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**ARAŞTIRMA MAKALESİ** **RESEARCH ARTICLE**

# Development of a Solar Powered Seeder for Pea Seeds

**Mohamed Ali Ibrahim AL-RAJHİ[1*], Yasser Kamal OSMAN[2], Enas Lokman Abdellatif SALEM[3]**

## Abstract

One of the most profitable vegetable crops for farmers to plant is peas. Pea seeding by hand is still one of the most tedious techniques farmers use today. Pea seed sowing requires a more significant number of skilled workers. The soil is dug by one person, and the pea seeds is sown there by another. Regarding farmers, the availability of skilled labor is still another issue. Egypt has many small farms; hence, it is necessary to produce small-scale farming machinery. Thus, this research manufactures a solar-powered seeding mechanism exclusively for small farmers at a low cost to overcome the problems of a lack of labor skills, sowing times, labor cost, accurate seeding, and seed losses. Increase profit for farmers who plant vegetable crops. The machine is provided with an accurate system to achieve accurate seed distribution. A complex gear mechanism is replaced with a sensor to make seeding simpler. There is an input LCD screen to sow at various distances between seeds. The distance between rows can be maintained. Also, there is a solar tracking system, which is essential for receiving more direct sunlight. Also, the motors used are 12 volts, so they are compatible with the electricity produced from the solar panel without the need for a voltage converter, which reduces costs. Also, both fuel costs and air pollution do not exist. The study includes two experimental variables: four theoretical hill spacings of 15, 18, 21, and 24 cm and four sowing depths of 2, 3, 4, and 5 cm. The measurements include the plant's longitudinal dispersal, lateral dispersal, emergence percentage, and operating costs. The minimum values of longitudinal and lateral dispersal and the highest value of emergence percentage were obtained at a theoretical hill spacing of 24 cm and a sowing depth of 5 cm. The developed machine can lower the operational cost by 94.96%, as one skilled worker can adequate complete the seeding operation. Therefore, it is suggested to use the solar-powered system for seeding pea seeds in small-scale farming.

**Keywords:** Agriculture, Manufacture, Seeds, Solar energy, Sowing machine

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## 1. Introduction

Pea is a popular and nutritious pulse crop from the leguminous family. About 22 million tons and 14.5 million tons of dried and green pea seeds are produced globally annually. In Egypt, peas are cultivated in an area of 801,4.02 faddan, with a production of 229.29 tons per year from dry peas and 156,249.98 tons from green peas (FAOSTAT, 2021). Pea seeds are famous for their essential nutrients, primarily soluble and insoluble fibers, proteins (lysine and tryptophan), complicated carbohydrates, folate, B vitamins, and minerals such as iron, potassium, and calcium, but minimal in cholesterol, saturated fat, and salt. Green seeds contain 17-22 g of carbohydrates, 14-26 g of dietary fiber, 20-50 g of starch, 0.4 g of fat, 6.2-6.5 g of protein, and 1.0 g of ash per 100 g. They also contain 9-10 mg of calcium, 97-99 mg of potassium, 3-5 mg of sodium, 0.7 mg of riboflavin, 5-6 mg of thiamine and 0.54-mg folate per kg (Goswami and Shukla, 2019; Kaiser et al., 2019; Millar et al., 2019; Robinson et al., 2019).

The main goals of the sowing process are to distribute seeds properly, put soil over them, and compact it around them. Most farmers still use the old method of sowing pea seeds. Peas are traditionally planted using a method that requires a lot of experienced laborers and considerable labor costs. One person must prepare the soil, and another must plant the pea seeds in the prepared soil. More laborers are needed for this kind of seeding activity, resulting in inefficient and inaccurate seed sowing. The cost of labor has been rising significantly over the past few years. Moreover, because of the lack of skilled labor, seeding peas takes longer and becomes more tedious.

Especially with the scattered holdings, small machines are considered helpful in Egypt. Also, the production and productivity of pea seeds as a vegetable crop were relatively low in Egypt. The reasons for low production and productivity were the unavailability of machines in the cultivated field. Most of the farming work in Egypt is done manually, compared with other countries. There were no machines for seeding pea seeds, and it is done by laborers only, so the cost was higher and the speed of the operation was lower.

The planter's main parts are hopper, metering system, and furrow opener (Ani et al., 2016). The metering device, which comes in various forms, is the brain of the seeder. The metering system prevents skipping, doubling, and damage to the seeds during seeding by releasing the seeds at the correct pace and creating the precise spacing required for high yields (Rabbani et al., 2016). According to Bashiri et al. (2013), sown tubes are a passage used to transmit seed from the seeds container into opening furrows. Furrow openers prepare the soil for dropping by covering the metered seeds and falling via the seed tube. When developing furrow openers, seeding depth should be considered (Ani et al., 2016).

Egypt also receives sunlight. Based on the solar atlas, it receives 3,050 hours of sunlight each year, with indirect normal irradiations varying from 1,970-3,200 kWh $m^{-2}$ and total annualized irradiance varying from 2,000-3,200 kWh $m^{-2}$. Therefore, according to Moharram et al. (2022), Egypt has excellent solar resources that may be used for several industries and solar energy systems.

Swetha and Shreeharsha (2015) designed a machine that uses a solar panel to absorb solar energy, transform it into electricity, and then use that electricity to charge a 12 V battery, which in turn powers a shunt-wound motor to perform tasks like digging, sowing seeds, pouring water, and fertilizing. Rohokale et al. (2014) compared the differences between conventional and modern seed-sowing procedures through the developed machines. Also, they calculated the row-wise spacing, and seeding rates, which vary for each crop. Also, these complicated issues are overcome with the development of their idea of the machine. This machine has decreased skilled labor, sowing times, maintenance costs, and labor costs (Mishra et al., 2017) successfully. Later, the design, development, and construction of a machine that can sow seeds, is operated by a toggle switch, and runs on solar and battery power were completed (Shree Harsha et al., 2017). Researchers have created devices that could perform tasks like autonomous sowing. Moreover, it offers manual management as necessary (Bute et al., 2018).

Pundkar and Mahalle (2015) developed high-precision pneumatic planters for various crops and seed sizes that uniformly distribute the seeds along the travel path. Also, Umarkar and Karwankar (2016) developed an agribot for reducing the cost of working and the period of digging for seeding. The effects of various seeding methods, machines, and rates of seed treatment on the establishment of seed-emergence plants and grain yield were determined by Sujon et al. (2018).

In order to supply sufficient electric power, solar panels could be used anywhere in the world (Turkboylari and Yuksel, 2021). It is clean and environmentally friendly compared to fossil fuels (Turkboylari, 2018). So, we can use a solar-powered machine to plant pea seeds and provide a seeder at a low cost compared to the available machines. Therefore, this study aims to: develop a solar-powered seeder that is renewable for sowing peas that is more ecological and needs little manual labor; facilitate the improvement of small-scale farming with the utilization of the new machine; study the optimal operation conditions for the assessed machine to optimize longitudinal and lateral dispersing; maximize emergence percentage, minimize costs; and overcome the disadvantages of the manual method.

## 2. Materials and Methods

Pea (*Pisum sativum* L.), namely cvs; Master, was used to test the manufactured machine. It is a dwarf modern variety, as its vegetative growth is limited, except that the length of the pod reaches 14 cm and contains about 10–12 seeds, and thus it outperforms all short varieties with an increase in the percentage of neglect, as it reaches 55–60%. The nodes are on the eighth node. The average length, width, thickness, and thousand seed mass were 7.6 mm, 6.5 mm, 5.5 mm, and 180.12 g, respectively, at a moisture content of about 10% on a dry basis. The amount of seed planted per feddan is about 35 kg. The germination percentage for laboratory conditions for the tested seeds was 98%.

### *2.1. Description of the manufactured machine*

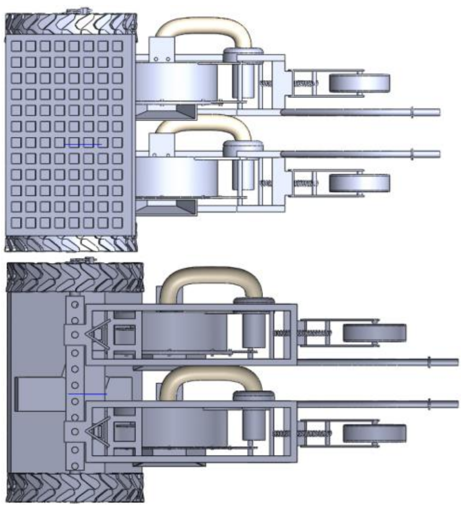
It has a frame assembly mounted on two drive wheels and a solar panel to absorb solar energy, which is then transformed into electrical energy. Seeds are fed to the seed metering mechanism by two hoppers on either side of the machine, and a two-motor systems is used to operate the seeding metering device. The machine was made in a local workshop. Two driving handles have been modified for quick movement and simple pea seeding. An acceptable working width of 70 cm was selected to allow seeding at vast distances. *Figures 1* and *2* show the developed machine's components, and Figure 3 shows the assembled parts in their ideal places. The layout of components was modeled using Solidworks software. Specifications are listed in *Table 1*.

***Table 1 The specifications of the machine***

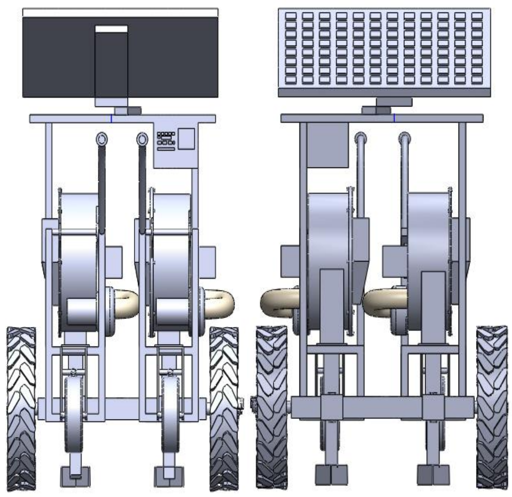
| | |
|---|---|
| Power source | - solar panel 50 kw for operating 4 motors (2 for metering devices and 2 others for vacuum) |
| Dimensions | length, 117 cm<br>width, 76 cm<br>height, 122 cm |
| Weight | 78 kg |

***Figure 1. The machine's rear View and right side***

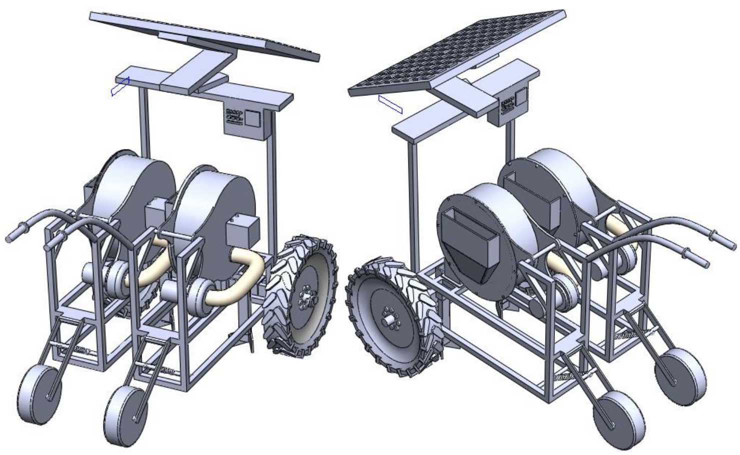
***Figure 2. The machine's front View and left side***



*Top and bottom View of the seeder*



*Front and rear View of the seeder*



*Right and left isometric View of the seeder*

***Figure 3. Design for the proposed machine***

- ***The frame*** was created as the backbone for the other components, with a length of 80 cm, to achieve smooth operation as intended. The whole thing is mounted on it in a suitable arrangement. The chassis has a variable width, but it was set at 60 cm to match the planning row spaces and make turning the machine easier. The chassis was made from an L-shaped plate to sustain various loads. Two rubber wheels of 40 cm diameter and 10 cm width fixed on a 3 cm shaft make up the two-wheeled chassis. The machine's wheels must be strong enough to carry the whole machine.

- ***The front two openers*** have dimensions of 15 cm in length and 10 cm in width. They are curved with a support structure that is 45 cm high and is used to dig the furrow and sow the seeds. The removable bolts and nuts attach the opener to the frame at the front.

- ***The hopper's*** capacity entire capacity is about 6 kg of pea seeds, and the conveyor receives sorted seed drops from the conical structure.

- ***A portable solar panel*** (peak power: 50 watts, maximum current: 2.81 amps, peak voltage: 22.1 volts, allowed voltage: 12 volts, dimensions: 600×400×25 mm) that is put on top of the machine and used to charge the 12 V battery. A solar charge controller is installed between the solar panel and the battery to regulate the voltage from the solar panel. A battery provided the electric power needed to run four motors (12 V) (two for operating the metering devices and two for vacuum) and produce mechanical work. Since the solar panel should always be positioned with its face towards the sky and be as vertical as the sun. The solar panel has a circuit with two photocells and a tracking motor that follows the sun's disc at an inclination angle of 30°, as shown in Figure 4.

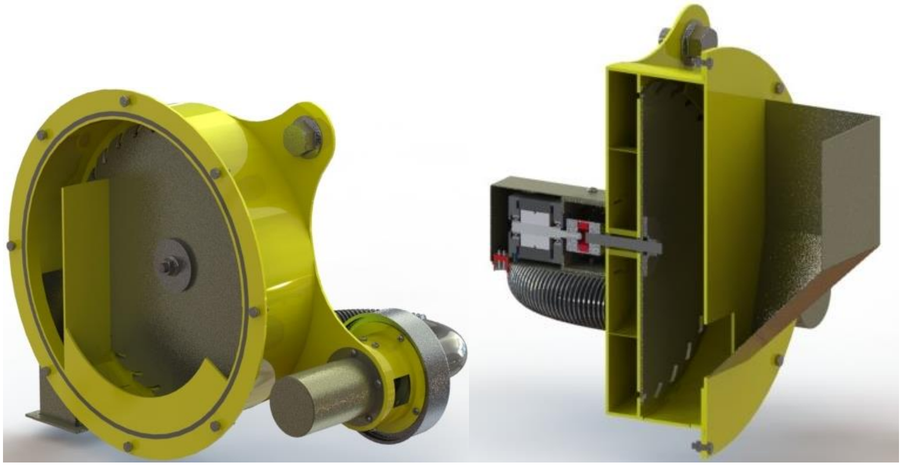
***Figure 4. Photovoltaic panel position***

- ***The driver*** gets a signal from the controller and amplifies it. Thus, they gain a higher voltage and convert it to suit the machine. This will prevent the motors from being damaged.

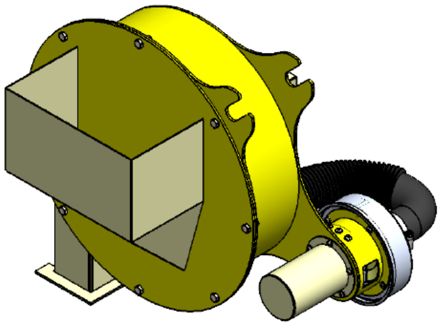
- ***LCD*** is used to enter the distance between two seeds and display it.

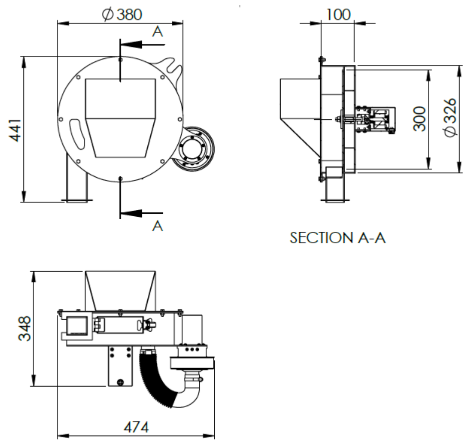
- ***A pair of handles*** displaying backwardly from the frame. The handles extended on either side, allowing the operator to push and direct the machine.

- ***The vacuum-based seed metering device*** consists of two circular plates arranged in a suitable manner. These plates are housed in the hopper. When the metering device is in operation, seeds are sucked and rotated by the plates until they reach point of atmospheric pressure. The pea seeds are then delivered to the seeding hose through a designated arrangement, as shown in Figure 5. This technology automates the seeding process, replacing manual labor and making sowing easier. Prior to delivery, a suitable cultivator arrangement is prepared to prepare the ground for seed sowing.

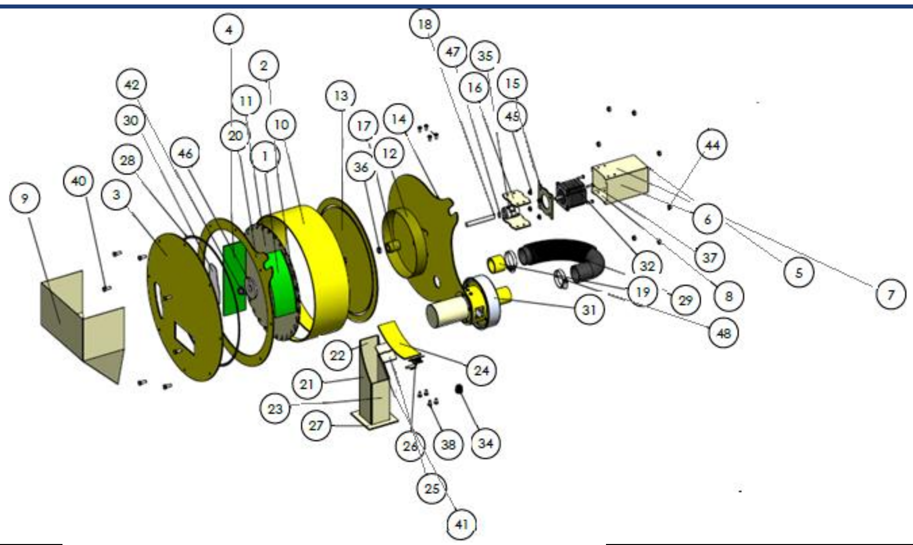


***The vacuum-based seed metering device***



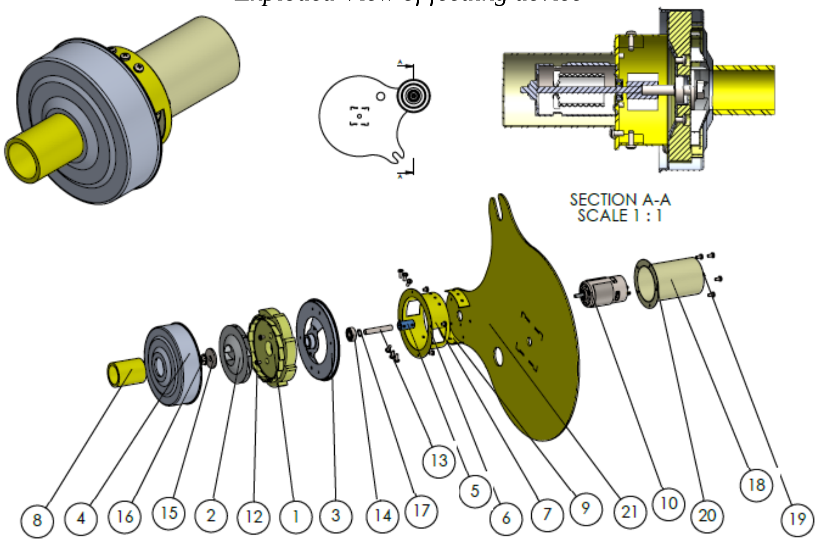



*Isometric View of feeding device* *A schematic diagram of the feeding device*



| N. | PART | QTY. | N. | PART | QTY. | N. | PART | QTY. | N. | PART | QTY. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Singulator Holder | 1 | 13 | Suction Track | 1 | 25 | Door Hinge | 1 | 37 | B18.6.7M - M4 x 0.7 x 16 Type I Cross Recessed PHMS --16N | 4 |
| 2 | Singulator | 1 | 14 | Outer Ring Back Cover | 1 | 26 | clamps a20 ass | 1 | 38 | B18.6.7M - M5 x 0.8 x 10 Type I Cross Recessed PHMS --10N | 8 |
| 3 | Outer Ring Front Cover | 1 | 15 | Stepper Holder Base | 1 | 27 | Seeds Outlet C | 1 | 39 | B18.6.7M - M3 x 0.5 x 10 Type I Cross Recessed PHMS --10N | 2 |
| 4 | Seed Track Saver | 1 | 16 | Stepper Holder Bracket | 2 | 28 | Front Cover Rubber Gasket | 1 | 40 | B18.2.3.1M - Hex cap screw, M6 x 1.0 x 16 --16N | 8 |
| 5 | Stepper Cover Back | 1 | 17 | Suction Track Spacer | 1 | 29 | Suction Tube 3 | 1 | 41 | AM -- M5 x 45 N | 1 |
| 6 | Stepper Cover T&B | 2 | 18 | Motor Axle Shaft | 1 | 30 | Acrylic Window | 1 | 42 | B18.2.2.4M - Hex flange nut, M10 x 1.5, with 15 WAF --N | 1 |
| 7 | Stepper Cover R&L | 1 | 19 | Fixed Suction Pipe | 1 | 31 | Vacuum Cleaner Motor | 1 | 43 | B18.2.4.1M - Hex nut, Style 1, M4 x 0.7 --D-N | 4 |
| 8 | Stepper Cover R&L+ | 1 | 20 | Front Cover Tension Face | 1 | 32 | stepper motor_NEMA 23 | 1 | 44 | B18.2.4.1M - Hex nut, Style 1, M6 x 1 --D-N | 8 |
| 9 | Kados | 1 | 21 | Seeds Outlet 1 | 2 | 33 | Motor - RS-775 | 1 | 45 | B18.22M - Plain washer, 4 mm, regular | 4 |
| 10 | Outer Ring | 1 | 22 | Seeds Outlet 2 | 1 | 34 | connector Bais ( 4 pin ) | 1 | 46 | B18.22M - Plain washer, 16 mm, wide | 1 |
| 11 | Cells Plate | 1 | 23 | Seeds Outlet 3 | 1 | 35 | Coupler D30L35-6.35-10.0 | 1 | 47 | B27.7M - 3AM1-11 | 1 |
| 12 | Inner Ring | 1 | 24 | Seeds Discharge Door | 1 | 36 | AFBMA 12.1.4.1 - 0100-15 - Full,DE,AC,Full_68 | 2 | 48 | Hose Clamp 44mm | 2 |

*Exploded View of feeding device*



| ITEM NO. | PART NUMBER | QTY. |
|---|---|---|
| 1 | Base Plastic Face | 1 |
| 2 | Vacuum Bit | 1 |
| 3 | Base | 1 |
| 4 | Face | 1 |
| 5 | Shaft Coupler_5 - 8 mm | 1 |
| 6 | Base Motor Connector | 1 |
| 7 | Base Motor Connector 2 | 1 |
| 8 | Air Outlet Extender | 1 |
| 9 | Base Motor Connector 4 | 2 |
| 10 | Motor - RS-775 | 1 |
| 12 | B18.6.7M - M4 x 0.7 x 8 Type I Cross Recessed PHMS --8N | 17 |
| 13 | continous stud_am | 1 |
| 14 | AFBMA 12.1.4.1 - 0080-22 - 8.SI.NC.8_68 | 1 |
| 15 | B18.22M - Plain washer, 8 mm, wide | 1 |
| 16 | B18.2.2.4M - Hex flange nut, M8 x 1.25 --N | 1 |
| 17 | B27.7M - 3AM1-10 | 1 |
| 18 | Motor Cover | 1 |
| 19 | Motor Cover Top 2 | 1 |
| 20 | Motor Cover Top | 1 |
| 21 | Outer Ring Back Cover | 1 |

*Exploded View of suction device*

***Figure 5. Feeding device***

- ***The wheel-fixed sensor*** converts rotation into the distance for seed sowing at a particular distance. Also, there is an input LCD that can be adjusted to plant seeds at various distances on the same line.
- ***The control panel*** holds all the components needed to run the system.

The main feature of the seeding process is shown in Figure 6. The feeding two units are powered by a solar panel connected to a 20 amp, 12 volt battery. Each unit consists of two main components: the first is the seed metering device, which includes a perforated plate with an installed stepper motor. The input unit consists of a rheostat (variable resistance) and a digital screen LSD that operates based on signals received from the wheel-fixed sensor. The second component involves a vacuum motor responsible for vacuuming the seeds and adhering them to the perforated plate until they are released into the seeding hose. The suction speed can be adjusted using the input unit, which includes the same rheostat (variable resistance) and an LSD digital screen.

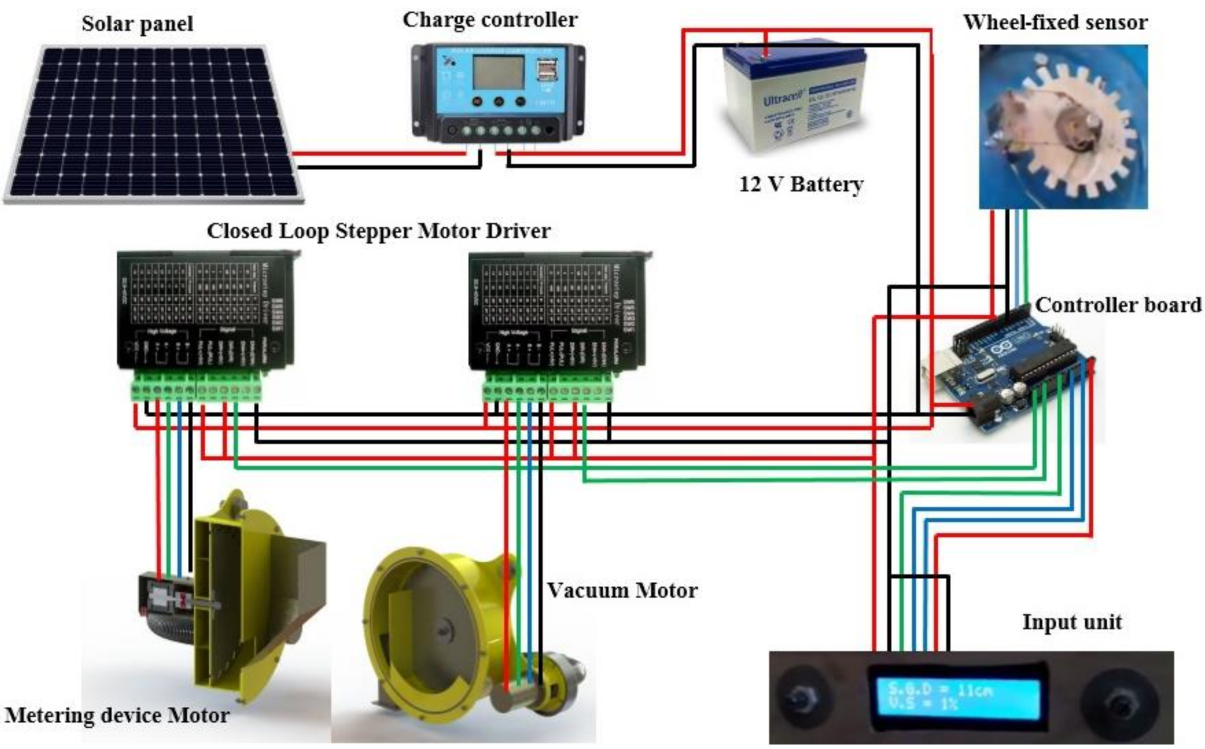



***Figure 6. The main feature of the seeding process***

- **The articulated covering and compacting wheels** are two wheels attached to two axes and hinged on either side, supported with two attraction springs, and used after the seeds are placed in the furrowed land to cover the sown and apply appropriate pressure to the seeds.

### *2.2. Principles of operation*

The main working principle of the developing machine is precision agriculture, which uses sensors to enable, for example, more efficient seeding. In this study, a complex gear mechanism is replaced with a sensor to make seeding simpler. The sensor converts rotation into the distance for certain seed sowing distances. Also, an input LCD screen can be adjusted to sow at various distances between seeds. With this machine, the distance between rows can be effectively maintained by securely attaching the axle of the two wheels, which are provided with several holes, to a hollow square main shaft. To modify the two seeding units, a square-shaped enclosure is mounted around the main hollow square shaft, featuring several holes along the shaft that allow for precise modification of the seeding distance as seeding is done in two rows simultaneously. As a result, this machine sows seeds with great accuracy and efficiency. Most solar panels are statically oriented, fixed at a certain angle towards the sky. As a result, the solar panel receives less direct sunlight, both in terms of time and intensity, which causes the P.V. cells to produce less power. The solution to this problem is a solar tracking system essential to optimizing solar energy. Also, the motors used are 12 volts, so they are compatible with the electricity produced from the solar panel without the need for a voltage converter, which reduces costs. Also, both fuel costs and air pollution do not exist. According to a statistical survey, Egypt has many small farms; hence, it is necessary to manufacture small-scale agricultural machines suitable for small holdings. *Table 2* shows the distribution of fields in Egypt (MOAGS, 2016).

***Table 2. The distribution of fields***

| Region | The percentage size of landholding (Fed.) | | | | |
|---|---|---|---|---|---|
| | <1 | 1 to <3 | 3 to <5 | ≥ 5 | Total area, fed. |
| The lower part of Egypt | 29.28 | 32 | 11.76 | 26.96 | 5,916,546.1 |
| The upper part of Egypt | 42.31 | 35.89 | 10.95 | 10.85 | 3,085,823.6 |

### *2.3. The experimental procedure*

The trials were completed at the Faculty of Agricultural Engineering, Al-Azhar University, Cairo, Egypt. The initial experiments were conducted in the laboratory to determine grain germination as an indicator for loss in germination in the field and some physical and mechanical properties of pea seeds.

#### *2.3.1. Variables that were evaluated*

Studies were conducted on two variables.

- Theoretical hill spacing, cm: four theoretical hill spacings of 15, 18, 21, and 24 cm, respectively, were studied.
- Sowing depths, cm: three sowing depths of 2, 3, 4, and 5 cm were studied. The sowing depth can be adjusted with the help of a screw arrangement.

#### *2.3.2. Measurements*

- ***The coefficient of variation of plants' longitudinal dispersal*** was calculated by determining the deviation in the longitudinal line at a distance of 10 m along the sowing row, and it was measured as follows:

$$sd = \sqrt{\frac{\sum(x - x^{-})^2}{n}} \quad \text{(Eq. 1)}$$

$$C.V. = \frac{sd}{x} \times 100 \quad \text{(Eq. 2)}$$

where sd is the standard deviation, x is the spacing between plants at 10 m along the seeding row, $x^{-}$ is the mean spacing between plants at 10 m along the seeding row, n is the number of observations, and C.V. is the coefficient of variation.

- ***Lateral dispersing*** was calculated by determining the cross-dispersed grains along the row, and the location of the plants along the center of the row was determined after 14 days of seeding and irrigation. The number of plants at each 10-meter interval along the row was compared to estimate the distribution. This relationship was employed for each experiment using the frequency distribution curve.
- ***The emergence percentage*** was also determined after 14 days of seeding and irrigation by using the equation below:

$$Emergence, \% = \frac{N_{ac}}{N_{th}} \times 100 \qquad \text{(Eq. 3)}$$

$N_{ac}$ is the actual plant number at 10 m long, and $N_{th}$ is the theoretical plant number at 10 m long.

- ***The total operating cost, EGP/h,*** was estimated according to the following:
- ***Fixed costs, EGP/h***
- $Depreciation\ costs = \frac{Machine\ price - 0.1 \times Machine\ price}{The\ Machine\ life, 5\ years}$ (Eq. 4)
- $Interest\ costs = \frac{Machine\ price + 0.1 \times Machine\ price}{2} \times 0.12$ (Eq. 5)
- Costs for shelter, taxes, and insurance were estimated to represent 3% of the machine's price.
- Then fixed costs = $\frac{Depreciation\ costs + Interest\ costs + Shelter, taxes\ and\ insurance\ costs}{hours\ of\ use\ per\ year}$ (Eq. 6)
- ***Variable costs, EGP/h***
- $Repair\ and\ maintenance\ costs = \frac{100\%\ Depreciation\ costs}{hours\ of\ use\ per\ year}$ (Eq. 7)
- $Labor\ costs = Salary\ of\ one\ worker \times Number\ of\ workers$ (Eq. 8)
- Then variable costs= $Repair\ and\ maintenance\ costs + Labor\ costs$ (Eq. 9)
- $\boldsymbol{Total\ cost, EGP/h} = fixed\ costs + variable\ costs \rightarrow$ (Eq. 10)

### *2.3.3. Statistical analyses*

M.S. Excel (Microsoft Corporation, Redmond, WA, U.S.A.) was used to edit the data. To evaluate the machine, a factorial design for the experiment was used. The experiments were performed five times, and Microsoft Excel 2021 was used to draw each graph. The obtained data are analyzed statistically by using a computer program (SAS., 2012).

## 3. Results and Discussion

### *3.1. Factors affecting hills' lateral dispersing*

*Figure 8* shows the effect of theoretical hill spacing between plants and sowing depth on hills' lateral dispersion around the centerline. Increasing the theoretical hill spacing and sowing depth decreases lateral dispersion and vice versa. This finding could be because the machine is well-designed with has less vibration.

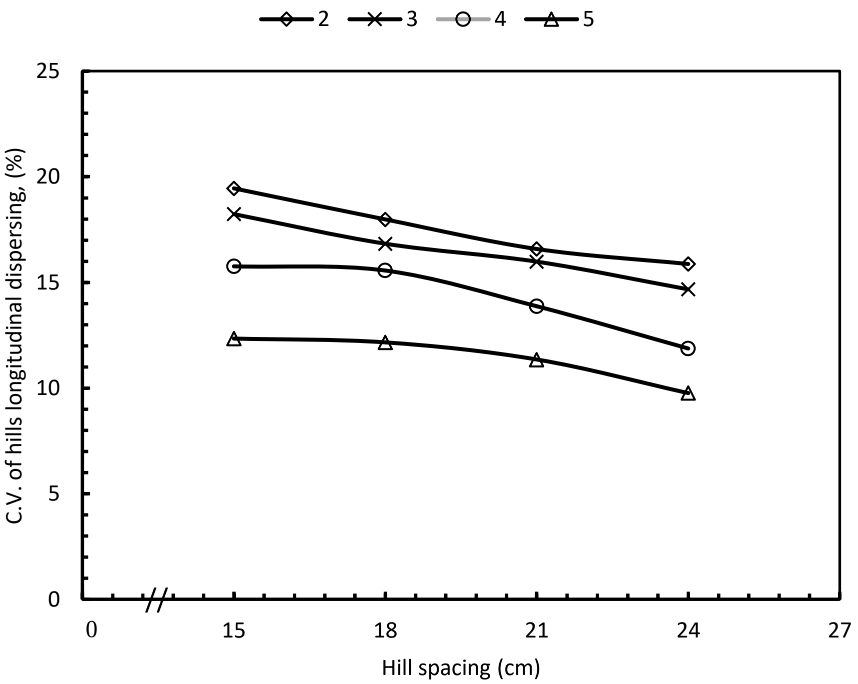



***Figure 7. Effect of sowing depth (cm) and theoretical hill spacing between plants (cm) on the coefficient of variation of plants longitudinal dispersing (%).***

### *3.2. Factors affecting the coefficient of variation of plants' longitudinal dispersal (%)*

*Figure 7* shows the relationships between theoretical hill spacing between plants and the coefficient of variation of plants' longitudinal dispersal at different levels of sowing depth. Increasing the hill spacing indirectly decreased the coefficient of variation of plants' longitudinal dispersing by increasing the various levels of sowing depth. However, the mean best value for the coefficient of variation of plants longitudinal dispersal was 9.76%, directly related to a theoretical hill spacing of 24 cm and a sowing depth of 5 cm. The mean maximum value for the coefficient of variation of plants longitudinally dispersing was 19.45% at a theoretical hill spacing of 15 cm and a sowing depth of 2 cm. According to Coates (1992), a coefficient of variation under 10% is regarded as excellent, while a value under 20% is typically regarded as acceptable for most field applications.

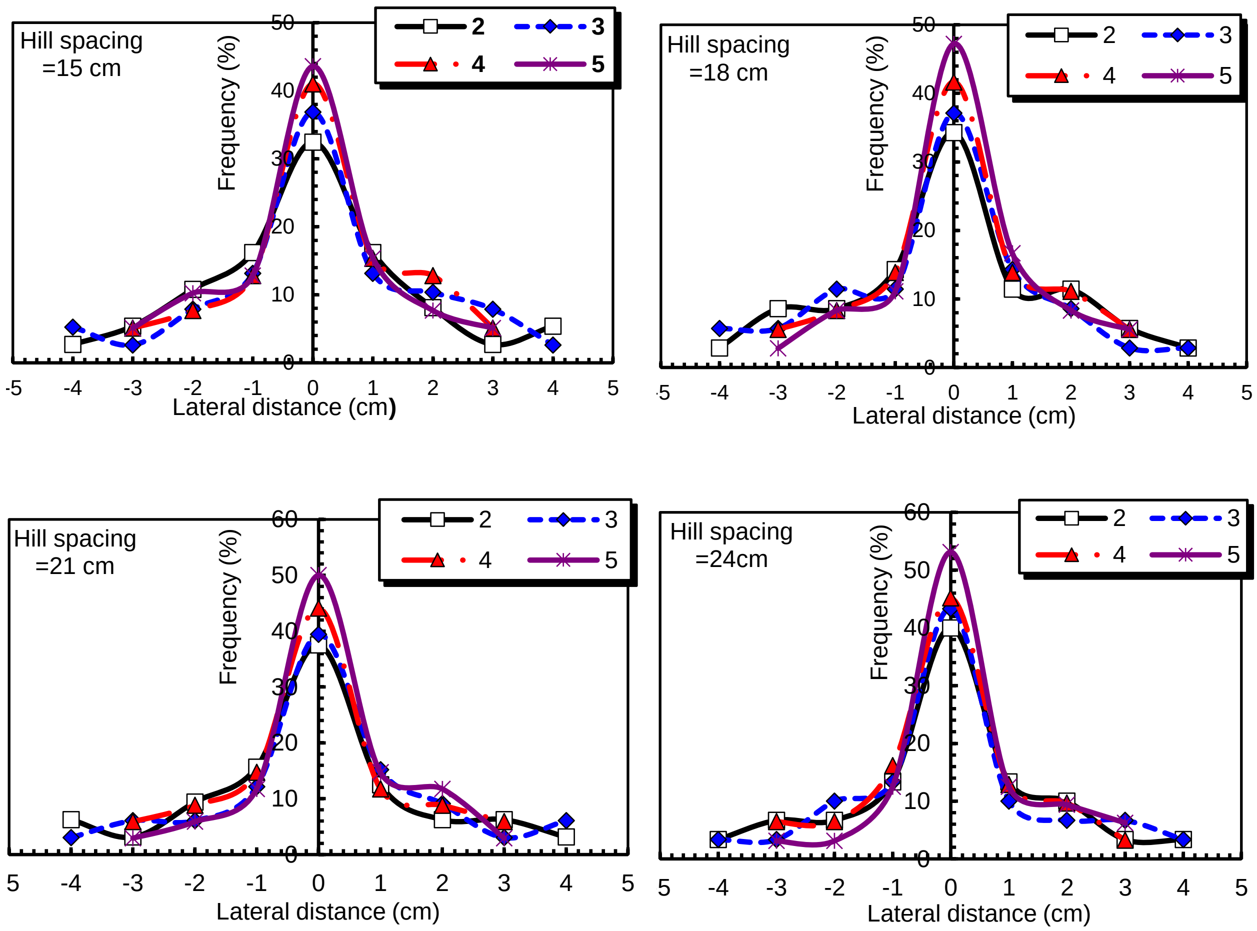



***Figure 8. Effect of sowing depth (cm) and theoretical hill spacing between plants (cm) on hill lateral dispersal.***

A simple power regression analysis was used to relate the change in the coefficient of variation of hills' longitudinal dispersing with the change in the tested factors for all treatments

The regression equation was C.V. (%) = 29.296 -2.025 $S_d$ - 0.3758 $H_s$ ($R^2$=0.9582), where $S_d$ is sowing depth, and $H_s$ is hill spacing.

### *3.3. Factors affecting emergence (%)*

*Figure 9* illustrates the correlation between theoretical hill spacing and the average emergence percentage at various sowing depths. Increasing theoretical hill spacing and sowing depth improved the mean emergence percentage. The highest value of the mean emergence percentage was 93.26% for theoretical hill spacing of 24 cm and a 5 cm sowing depth. The minimum value of the mean emergence percentage was 83.23% for theoretical hill spacing of 15 cm and a 2 cm sowing depth.

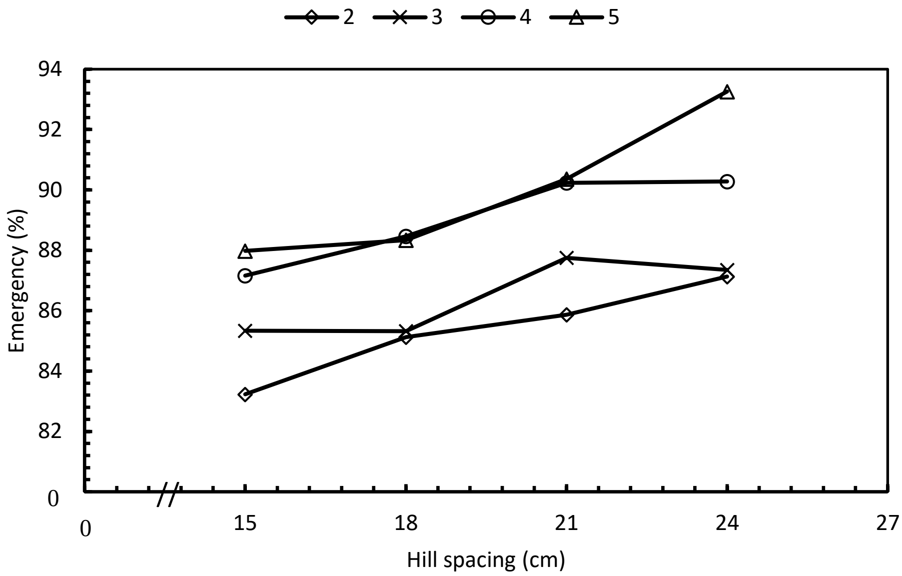



***Figure 9. Effect of sowing depth (cm) and theoretical hill spacing between plants (cm) on emergence (%)***

The obtained regression equation was emergence (%) = 73.73 + 1.660 $S_d$ + 0.4181 $H_s$ ($R^2$=0.9267).

The current results indicated that the sowing depth had Significant effects on both of longitudinal dispersing and emergence percentage (p<0.0001). The increased sowing depth coupled by an ascending order for longitudinal dispersing as well as descending order for emergence. Regardless the effect of sowing depth, the effect of hill spacing also affected aforementioned two parameters significantly (p<0.0001, 0.0014, respectively). In contrast, the effect of the interaction between sowing depth and hilling spacing had not significant effects (p>0.05) (*Table 3*).

***Table 3. Means along with their standard error for longitudinal dispersing and emergence percentage affected by studied factors.***

| Items | Longitudinal dispersing (%) | Emergence (%) |
|---|---|---|
| **Sowing depth** | | |
| **2** | 19.47±0.79[a] | 85.33±0.81[b] |
| **3** | 18.42±0.74[a] | 86.44±0.64[b] |
| **4** | 16.26±0.90[b] | 89.03±0.75[a] |
| **5** | 13.40±0.58[c] | 89.98±1.25[a] |
| **Hill spacing** | | |
| **15** | 18.44±0.91[a] | 85.92±0.76[c] |
| **18** | 17.63±0.71[ab] | 86.81±0.61[bc] |
| **21** | 16.44±0.76[b] | 88.55±0.86[ab] |
| **24** | 15.04±0.80[c] | 89.50±0.93[a] |
| **p-Value** | | |
| **Sowing depth** | <.0001 | <.0001 |
| **Hill spacing** | <.0001 | 0.0014 |
| **Interaction** | 0.9776 | 0.9282 |

Lin; linear regression; Means within a row without a common superscript letter differ at p<.05.

### *3.4. Cost analysis*

*Table 4* shows the materials utilized for this project and its overall cost. The total fabrication cost of the seeder was about 3835 EGP (US 127.83 $) in 2023. The materials required were available in the local market.

***Table 4. lists the materials utilized for this project and its overall cost.***

| S/N | Material description | Quantity | Unit, EGP | Total, EGP |
|---|---|---|---|---|
| 1 | Metal | - | - | 420 |
| 2 | Arduino Board (Arduino Uno) | 1 | 200 | 200 |
| 3 | P.W.M. Board (kit mosfet board 15 A 400 W) | 1 | 30 | 30 |
| 4 | Bearings (ID : 10 mm , O.D. : 15 mm, T: 4.5 – 5 mm) | 1 | 30 | 30 |
| 5 | Cultivator | 2 | 50 | 100 |
| 6 | Rubber wheels (dia. 35 cm) | 2 | 100 | 200 |
| 7 | Pressure wheels (dia. 20 cm) | 2 | 50 | 100 |
| 8 | Springs | 2 | 10 | 20 |
| 9 | Insulation and paint materials | - | - | 50 |
| 10 | Circular plate | 2 | | |
| 11 | Bolts and nuts | - | - | 50 |
| 12 | Solar panel 600×400×25 mm | 1 | 350 | 350 |
| 13 | Solar charger controller | 1 | 200 | 200 |
| 14 | Photocell | 2 | 15 | 30 |
| 15 | Stepper motor Nema 23 | 2 | 45 | 90 |
| 16 | DC motors 12 V (775) | 2 | 180 | 360 |
| 17 | Stepper Motor Driver (TB6600 4A) | 2 | 100 | 200 |
| 18 | Battery (12 V – 7 A) | 2 | 200 | 400 |
| 19 | Incremental Optical Rotary Encoder (for Wheel " 360+ P/R - 500+ R/m ") | 1 | 250 | 250 |
| 20 | Rotary Encoder (for LCD Screen "KY040 ") | 1 | 20 | 20 |
| 21 | LCD Screen + IIC Board (2X16 Green) | 1 | 45 | 45 |
| 22 | Power Switches + LED + fan | - | - | 50 |
| 23 | 2 Pin Power Connectors (G.X. 16) | 4 | 8 | 32 |
| 24 | 4 Pin Power Connectors (G.X. 16) | 6 | 8 | 48 |
| 25 | Stepper Motor Coupler (6.35X10 mm) | 2 | 15 | 30 |
| 26 | DC Motor Coupler (Fixed 5X8 mm) | 2 | 15 | 30 |
| 27 | Vacuum Cleaner Turbin | 2 | 75 | 150 |
| 28 | Cables | - | - | 50 |
| Manufacturing | | | | 300 |
| Total machine price, EGP | | | | **3,835** (US 127.83 $) |

***Table 5. Comparing the total cost of the developed machine and the manual process.***

| Specification | Manufactured boat | Manual method |
|---|---|---|
| Machine price, EGP | 3,835 (127.83 $) | |
| Depreciation costs, EGP | 690.3 (23.01 $) | |
| Interest costs, EGP | 253.11 (8.44 $) | |
| Shelter, taxes and insurance costs, EGP | 115.05 (3.84 $) | |
| Fixed costs, EGP $h^{-1}$ | 0.147 (0.005 $ per hr) | |
| Repair and maintenance costs, LE $h^{-1}$ | 0.096 (0.003 $ per hr) | |
| Labor costs, EGP $h^{-1}$ | 1×30 =30 (1.0 $ per hr) | 20×30=600 (20 $ per hr) |
| Variable costs, EGP $h^{-1}$ | 30.096 (1.003 $ per hr) | |
| Total cost, EGP $h^{-1}$ | **30.243** (1.008 $ per hr) | **600** (20 $ per hr) |

$^{EGP}$ Egyptian pound
One U.S $ = 30 EGP

The total operating costs of the manufactured machine and the traditional manual method are compared in *Table 5*. Its expected life is about ten years. It is utilized eight hours a day, or about 90 days a year, so the total operating hours were 7,200. One skilled worker is adequate to complete the entire seeding operation, so the labor cost was 30 EGP per hr. (1.0 $ per hr.). In comparison, the manual method required twenty workers to sow the required crop on 4,200 $m^2$ per day, and this costs about 600 EGP per hr. (20 $ per hr). The manufactured machine can reduce seeding costs from 600 EGP per hr. (20 $ per hr) to 30.243 EGP/h (US 1.008 $ per hr), for an approximate 94.96% cost reduction ratio. As a result, the costs associated with paying labor payments will be significantly decreased, increasing farmers' profits. Moreover, labor time and effort are saved.

## 4. Conclusions

Egypt is a developing country that depends mainly on agriculture to feed its people. Especially with the scattered holdings, small machines are considered helpful in Egypt. Also, the production and productivity of pea seeds as a vegetable crop were relatively low in Egypt. With the latest technological improvements, the developed machine could make farming more feasible, affordable, and user-friendly. This research explored the possibility of utilizing new equipment for seeding pea seeds. Four theoretical hill spacings of 15, 18, 21, and 24 cm and four sowing depths of 2, 3, 4, and 5 cm were studied. The best values of longitudinal dispersing, lateral dispersing, and emergence percentage were obtained at a theoretical hill spacing of 24 cm and a sowing depth of 5 cm. The manufactured machine can reduce seeding costs from 600 EGP $h^{-1}$ (20 $ per hr) to 30.48 EGP $h^{-1}$ (1.008 $ per hr), for an approximate 94.96% reduction. It is recommended to utilize this machine for small and medium farmers to plant pea seeds and other seeds such as corn, soybeans, etc. To get more benefits and enhance the usage of this machine, it is recommended that it be used for spraying pesticides, etc. By utilizing this machine, we can enhance sowing rates while also protecting seeds from damage. Also, it can be utilized in small spaces, so it is very beneficial for small-scale farmers.

### Challenges and Future Studies

This machine will require human power to push it, which is a disadvantage. Efforts should be made to convert it to a self-propelled machine.

### Ethical Statement

There is no need to obtain permission from the ethics committee for this study.

### Conflicts of Interest

The authors declare that they have no known competing financial interest or personal relationships that could have appeared to influence the work reported in this paper. We declare that there is no conflict of interest between us as the article authors.

### Authorship Contribution Statement

Concept: Mohamed Ali Ibrahim Al-Rajhi, Yasser Kamal Osman, Enas Lokman Abdellatif Salem; Design: Mohamed Ali Ibrahim Al-Rajhi, Yasser Kamal Osman, Enas Lokman Abdellatif Salem; Data Collection or Processing: Yasser Kamal Osman, Enas Lokman Abdellatif Salem; Statistical Analyses: Mohamed Ali Ibrahim Al-Rajhi; Literature Search: Mohamed Ali Ibrahim Al-Rajhi, Yasser Kamal Osman; Writing, Review and Editing: Mohamed Ali Ibrahim Al-Rajhi, Yasser Kamal Osman.

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