



## **Concept Design of a Portable Carrot Seeder**

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### **Authors' contributions**

*This work was carried out in collaboration among all authors. All authors contributed in this study. All authors read and approved the final manuscript.*

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### **ABSTRACT**

A concept design of a carrot seeder, filed for patent application, was successfully developed in this study. Farmers were visited and interviewed and the data regarding their existing practices in planting carrots, corresponding tools and equipment and planting requirements such as hill spacing, row spacing and plant bed size were gathered. These data were used as input in the preparation and simulation of the seeder design with the aid of Solidworks software.

The seeder consisted of seed metering assembly, frame, ground wheels, skid, handle, power transmission, furrow opener and seed covering mechanism. It has 5 metering discs and the spacing between rows is adjustable. The metering disc is provided with grooves on its periphery of size that can accommodate 2 to 5 carrot seeds. Draft force to push the device in usage is 10 kg-force. The designed overall weight is 12 kg.

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## 1. INTRODUCTION

The High-Value Crops Development Program of the Department of Agriculture identifies carrots as one of the high value crops of the Philippines. The use of hand-held traditional tools in planting carrots in the Philippines is predominant since seeders available abroad are not directly adaptable to local farm conditions. The topographic conditions such as slope and size are some of the limiting factors on the mechanization in the country [1].

Carrot production in the Philippines is distributed over the Cordillera region (Benguet, Mountain Province, Ifugao), Nueva Vizcaya, Cebu, Davao del Sur, Negros Oriental, and Bukidnon. Among the production areas, 88.9% of the total production is coming from CAR [2]. The Cordillera Region being mountainous have farms that are usually non-contiguous, sloping and small in sizes.

Planting of seeds has to be done at a shortest possible time in the field so as to achieve uniform germination and avoid longer exposure of seeds. This can be accomplished by increasing the capacity of the seeder. Capacity is influenced by the effective working width [3]. Effective working width of seeder can be optimized with additional rows or metering discs making it a multi-row seeder. Planting machines for similar seeds with more rows had higher capacity. For instance, [4] determined that the capacity of a 10-row onion planter is  $0.41 \text{ ha hr}^{-1}$  and a 2-row onion planter has a capacity of  $0.21 \text{ ha hr}^{-1}$ . A double row planter for okra developed by Mofolasayo [5] was found to have a working capacity of  $0.36 \text{ ha-hr}^{-1}$ . Compared to a template row planter tested in maize and cowpea with a capacity of  $0.2 \text{ ha-hr}^{-1}$  [6]. However, planting accuracy can be sacrificed at extremely high or low capacity and it has to be improved, usually by adding optimum number of rows [7].

The important factor in seeder design is its accuracy to deposit seed into the soil which could result to reliable germination rate and uniform plant emergence [8].

Seed damage and seed distribution efficiency are also affected by the RPM of metering disc. Higher RPM can reduce distribution efficiency and increase damage of seeds [9]. Concluded that seed distribution efficiency of a jute seeder decreased from 91% to 86% at increased

metering disc RPM from 30 to 60. In a vertical metering mechanism, the RPM of the disc is related to its diameter. Small-sized disc has to rotate faster compared to disc of higher diameter. Relatively low seed damage of 3.51% in a two-row okra planter was due to the low speed as observed in the laboratory test [5].

The objectives of the design project were to establish design criteria of a carrot seeder; and develop a detailed design of a carrot seeder.

## 2. MATERIALS AND METHODS

### 2.1 Process Flow

The process followed in the study is presented in Fig. 1.

### 2.2 Benchmarking

Field survey were conducted to gather data and information on the practices of farmers in planting carrot seeds in the province of Benguet represented by the Municipalities of Buguias and Mankayan. This information was used to develop design criteria and design parameter of the device. Preferences of farmers with respect to a carrot seeder were collected during the survey. Data on the dimensions of plant bed, spacing between hills and rows and the number of seeds sown per hill were also gathered. A structured survey questionnaire following ISO 9001 procedure relating to user's perception and satisfaction was used to aid the data gathering [10]. Evidences were documented following similar procedure by [11] which include documentation, and note taking during the interview.

### 2.3 Design Criteria

The design criteria of the seeder were determined through the following:

#### 2.3.1 Operator's preference

The preferences of the farmers on carrot seeder with respect to mass, capacity in terms of preferred number of hours to plant a one-hectare field, and force required to operate the seeder were noted.

#### 2.3.2 Planting data

Existing tools used by the farmers from the preparation of the plant bed to planting were

documented and the functions of each tool were also noted. Spacing between hills and rows were recorded. The plant bed utilized for carrot production has unique dimensions and forms compared to other types of plant bed used for

other crops. It has certain canal depth, the bed width being dependent on the size of the wood puncher, length dependent on the land area. A typical plant bed for carrot production is shown in Fig. 2.

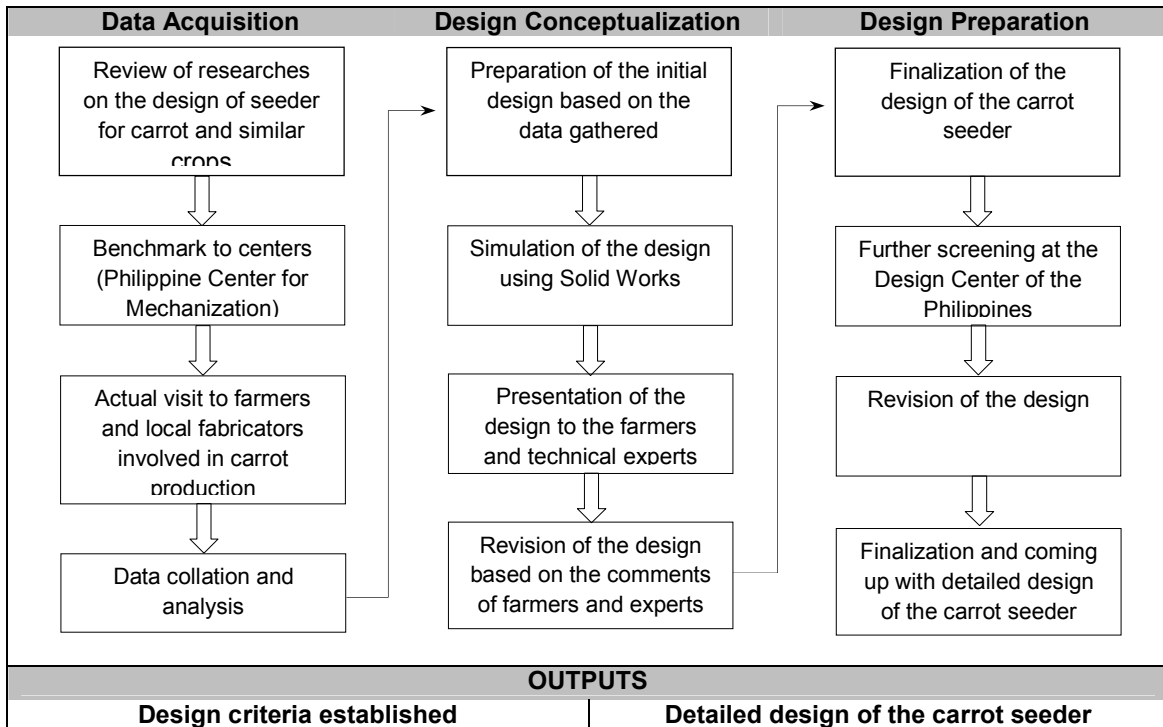


Fig. 1. Process flow of the study

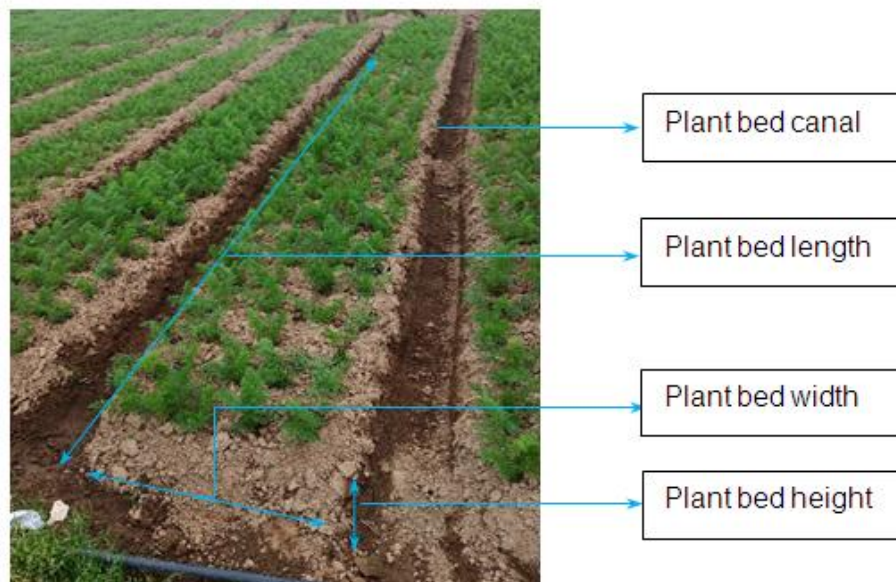


Fig. 2. Plant bed for carrot production

## 2.4 Design Parameters

The design parameters of the carrot seeder were determined as follows:

### 2.4.1 Capacity

The capacity was designed on a one-hectare basis, the number of hours to complete the planting operation as preferred by the farmers, and was calculated using Equation 1. This was also validated with the designed capacity of existing seeders.

$$C = \frac{A}{t} \quad (1)$$

Where: C is capacity in ha/hr; A is area in ha; and t is time in hours needed to complete the planting operation.

### 2.4.2 Operating speed

The operating speed of the seeder was designed to meet the preferred capacity. It was calculated using Equation 2. The appropriate size of the wheels appropriate to be operated at the designed capacity was also considered.

$$OS = \frac{2.7A}{EWW \times t}; \text{ or } = \frac{2.7C}{EWW} \quad (2)$$

Where: OS is operating speed in m/s; A is area of the testing field in hac; EWW is the effective working width of the seeder in m and t time of planting operation in hours.

### 2.4.3 Size of the metering disc

The diameter of the metering disc was designed based on standard hill spacing for carrots and the optimum number of seed cells for a vertical metering disc. It was calculated using Equation 3

$$D = \frac{HS \times NC}{\pi} \quad (3)$$

Where: D is the diameter of the metering disc; HS is the standard hill spacing for carrots in cm; and NC is the number of seed cells.

### 2.4.4 Seed cell

The size of the seed cell around the periphery of the metering disc was based on the maximum size of a carrot seed considering its major and minor diameter and it was designed to

accommodate 2 to 5 seeds. Optimum number of seed cells for seeders with vertical curricular metering disc served as basis in the design. Spacing of the seed cells was calculated using Equation 4.

$$S = \frac{c}{NC} \quad (4)$$

Where: S is the spacing between cells in cm; c is circumference of the metering disc in cm; and NC is the number of cells.

### 2.4.5 Metering disc speed

The metering disc rotational speed was designed based on the suggested optimum speed of a vertical metering disc from literature and relating it to the operating speed. It was calculated using Equation 5.

$$v = RPM \times \pi D \times 60 \quad (5)$$

Where: v is the peripheral speed of the metering disc, in number of RPM (Revolution Per Minute) of the ground wheel, and D is the diameter of the ground wheel.

### 2.4.6 Ground wheel

The diameter and width of the ground wheel were designed based on the operating speed and the standard spacing between plant beds. Commercially available wheels were also considered in the design.

### 2.4.7 Transmission

Chain and sprocket were used to transmit the rotational power of the ground wheel to the metering disc. Appropriate size of the sprockets, in order to deliver the required speed to the metering disc, was determined using Equation 6.

$$N_1 D_1 = N_2 D_2 \quad (6)$$

Where: N<sub>1</sub> and D<sub>1</sub> are the speed in RPM (Revolution Per Minute) and number of teeth of the driving sprocket; and N<sub>2</sub> and D<sub>2</sub> are the RPM and number of teeth of the driven sprocket.

## 2.5. Simulation

The concept design was prepared and simulated using a SolidWorks software. Initial design criteria were inputted and then were modified after the simulation procedure. In the simulation, stress and load analysis were carried out. Stress analysis was also verified using Equation 7.

Suggested construction materials for all components were considered in the final design.

$$\delta = F/A \quad (7)$$

Where:  $\delta$  is the stress, F is the force acting on the member; A is the cross-sectional area of the member.

### 3. RESULTS

#### 3.1 Concept Design

Based on the preference of the farmers, and the data gathered from the field a concept design of a carrot seeder was prepared shown in Fig. 3. The seeder comprises of metering mechanism which is responsible of discharging the seeds into the ground, ground wheels, transmission assembly, furrow opener, clutch assembly, handle and some accessories.

#### 3.2 Seeding Principle

The seeder is operated by means of pushing the handle that would cause the ground wheel to rotate. The metering discs which are in synchronous to the ground wheel by means of chain and sprocket will then be rotated. The seed metering assembly, as shown in Fig. 4, comprises of hopper, metering disc, and additional parts such as the seed discharge guide or stopper and furrow opener. The metering disc was designed to contact the hopper at a quarter of its circumference, which increases the chance of the seed cells to successfully load seeds during rotation.

The metering discs are arranged in series on an axle (Fig. 5). The metering disc axle is in turn connected to the axle of the ground wheel by means of a chain and sprocket.

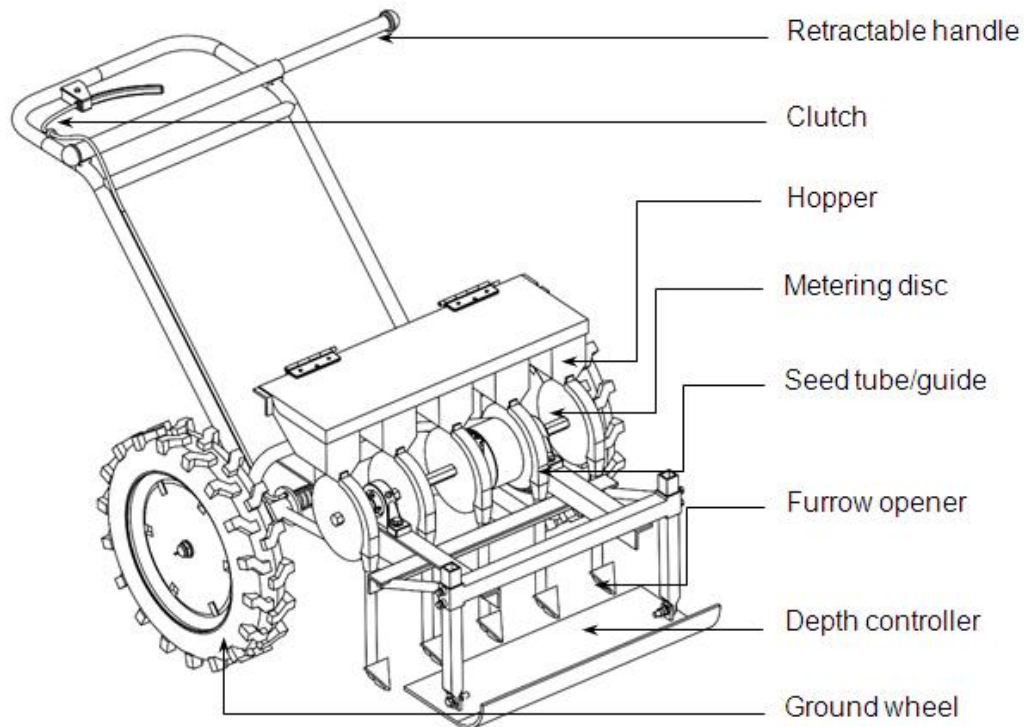
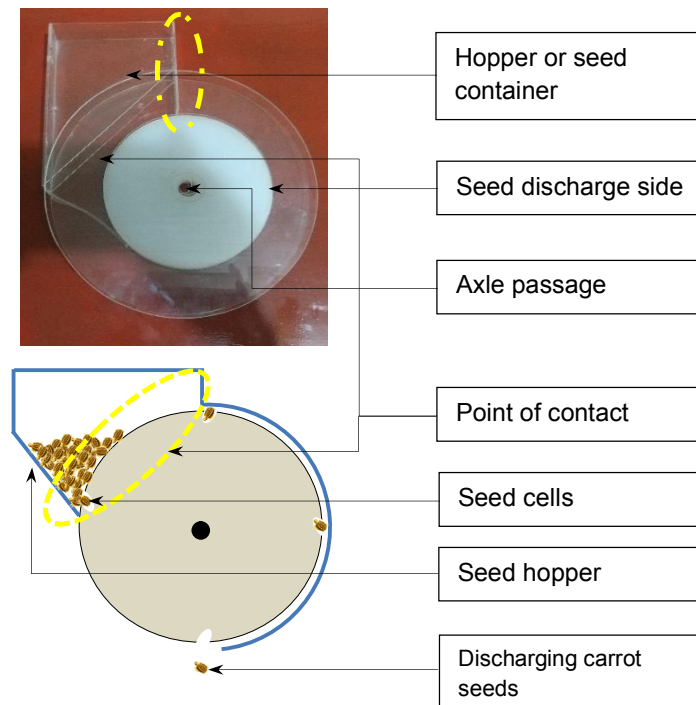
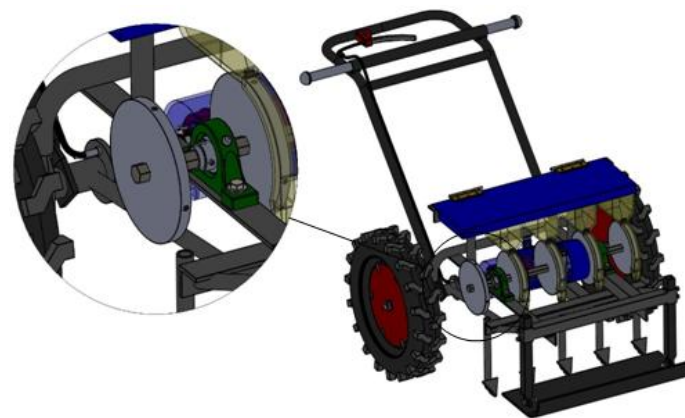


Fig. 3. Concept design of the carrot seeder



**Fig. 4. Metering mechanism of the carrot seeder**



**Fig. 5. Metering disc**

Provision to engaged and disengaged the metering discs is provided by means of a clutch assembly as shown in Fig. 7. This way the seeder can still be moved through its wheel during transport and maneuvering without rotating the metering disc.

Additional features to minimize the use of another pair of wheels at the rear portion of the seeder, a skid (Fig. 8) is designed that would serve as depth controller for the furrow opener. The skid is purposely designed to scrape flatten

the surface of the plant bed which makes the furrow opening more efficient. It is also served as depth controller so that the furrow opener will create furrow of uniform depth.

### 3.3 Specifications of the Seeder

The components of the seeder were designed to deliver the requirements for planting carrots. Table 1 presents the specifications of the seeder. The seeder was designed to plant seeds spaced at 12.5 cm between row and 10 cm between

hills. The metering discs can be adjusted in case planting spacing has to be changed. The metering discs are provided with cells around the periphery of size that can accommodate 2 to 5 seeds.

The overall mass was designed at 12.0 kg which is light enough for a farmer easily carry the device especially when transferring from one plant bed to another during operation. The furrow opener is designed to make a corrugation of 2.5 cm depth where the seeds will be placed.

### 3.4 Materials of Construction

The optimum size and materials for each part of the seeder is provided in Table 2. The materials were also reconciled with its availability in the local market and the ease of fabrication especially in local settings where fabricators do not have access to precision fabrication laboratory.

### 3.5 Recommended Criteria for Evaluation

The criteria to measure the degree of success of the design is presented in Table 3. This includes the dropping efficiency, coefficient of variation, seeding capacity, and driving force.

### 3.6 Recommended Plant Bed Settings

The plant bed has to be thoroughly prepared, free from clods and stones for optimum performance of the seeder [12]. There are some parts (Fig. 6.) of the plant beds that need to be prepared mainly in accordance to the dimension of the seeder. The dimensions are also critical to match the working size of the seeder. Plant bed height has to be 12.0 cm and top width is 50.0 cm. A clearance between the plant bed and the wheels

is also necessary to avoid the wheels from scraping the side of the plant bed that can affect the stability of the seeder. This clearance should be at least 5 to 8 cm. Plant bed canal is also important and should be spacious enough to allow the wheels to freely pass through and the operator as well.

## 4. DISCUSSION

The preparation of the design of the carrot seeder that involved the actual experiences and preferences of the farmers has made the design process more realistic and can maximize available construction materials. Most importantly, the design requirements on spacing between seeds and plant beds were simulated in the design which resulted to the recommended size of ground wheel, power transmission and the size of the metering disc.

Other researches use a drum type metering mechanism where seeds are inside the drum and the whole quantity of seeds are rotating with the drum [13]. A seed sowing machine by Thorat [14] used two row design for carrot and other crops mounted on a frame supported by 4 wheels. Similar number of wheels was also used by Kyada [15], it also used single row metering mechanism, where the metering disc loads seeds through the grooves on its side surface.

The metering mechanism in this work is designed such that the seeds will be staying at a steady position in the hopper except that it only flows toward the seed cell during rotation. Carrot planting design in the Philippines usually have 4 to 5 rows in each plant bed which was addressed by using adjustable metering discs. The carrot seeder has a market price ranging from PhP 10,000.00 to PhP 15,000.00 which is reasonable to the costing of material and fabrication cost. Table 4 shows the features of the new carrot seeder design compared with other existing designs.

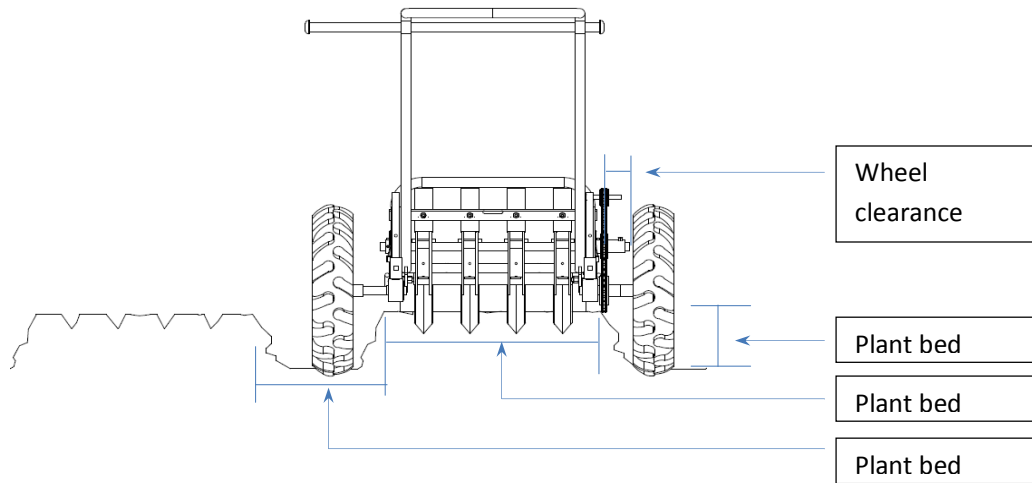
**Table 1. Specifications of the carrot seeder**

Parameters (as designed)	Dimensions
Row spacing	12.5 cm
Hill spacing	10 cm
Size of seed cell	Can contain 2 to 5 carrot seeds
Depth of seed placement	2.5 cm
Overall weight	≤ 12 kg
Draft requirement	10 kg-force

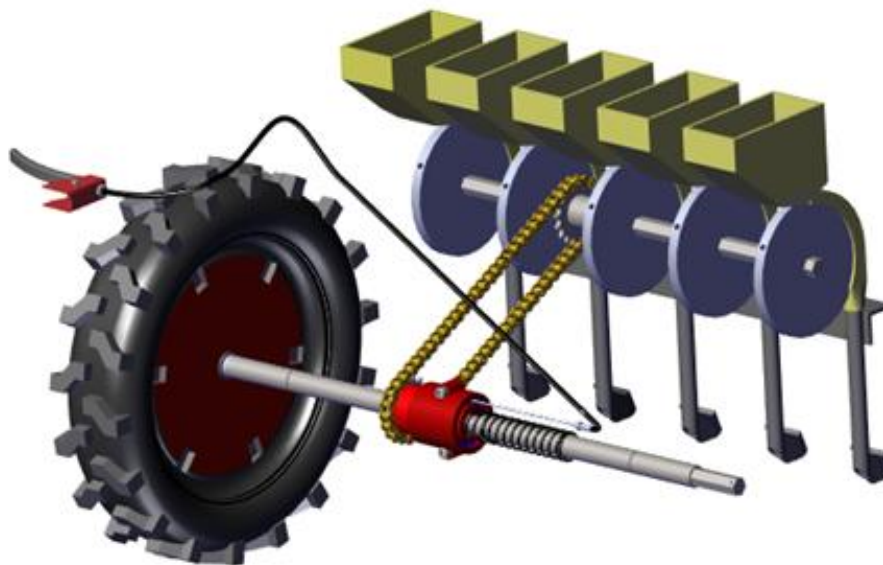


**Table 2. Materials of construction and size of seeder component**

Parts	Size	Materials
Handle	1.25 cm	GI Pipe Sch 40
Frame	1.25 cm	GI Pipe Sch 40
Metering Disc	14.28 cm x 5.08 cm	Polyethylene
Cover	0.10 cm thick	Fiber board
Ground wheel	40 cm	Pneumatic rubber wheel



**Fig. 6. Plant bed recommended settings for the proposed carrot seeder design**



**Fig. 7. Power transmission and clutch assembly of the carrot seeder**



**Table 3. Criteria for evaluation of the seeder**

Performance Parameters	Remarks
Dropping Efficiency, %	This indicates the efficiency of the device to drop the required number of seeds in each hill. It can be evaluated by getting the ratio of the number of hills containing the required number of seeds (2 of 5) to the total number of hills expressed in percent. The dropping efficiency should at least 90 to 95%.
Coefficient of Variation, %	This measures the characteristics of the device to discharge uniform number of seeds across the hills. The lower the CV, the more uniform is the distribution. In most seeders, the acceptable CV is at 10% or less.
Seeding capacity, hac-hr <sup>-1</sup>	This relates to the rate by which the seeder can accomplish the seeding operation. It is usually measured in Area per unit time. For the preference of the farmers form Table 1 capacity should be at least 0.25 hac hr <sup>-1</sup>
Draft force, kg-force	This is the force required to push the seeder in the actual farm setting. Horizontal force needed to push must be lesser than 5 to 10 kg force.

**Table 4. Specification of the seeder in comparison with other designs**

Parameters	This research	(Kyada, 2014)[15]	(Thorat Swapnil V, 2017)[14]	(Vinod Kumar, 2018)[16]	(Tumpa Rani Sarker, 2019)[17]
Metering mechanism	Disc	Seed plate	Seed plate	Seed plate	Drum type
Disc spacing (row sapacing)	Adjustable	Fixed	Fixed	Fixed	Fixed
No of metering disc	5 (can be reduced to 4)	1 (fixed)	2 (fixed)	1 (fixed)	
No of wheels	2	4	4	2	2
Seed cells orientation	Along the circumference of the metering disc	Side of the metering disc	Bucket type	Seed Roller	Holes around the drum
Material of metering disc	Flexi Glass	Metal plate	Metal bucket	Metal plate	
Scraper	Skid	-	-	-	None
Safety features	Use of clutch	-	-	-	
Ease of pushing	Provided with retractable handle	-	-	-	None
Draft requirement (Pulling /Pushing force)	10 kg force (Simulated)	-	-	-	13.25 kg -force
Estimated cost (PhP)	10,000 to 15,000	-	-	-	68.54
Weight (Kg)	12 kg	-	-	-	14

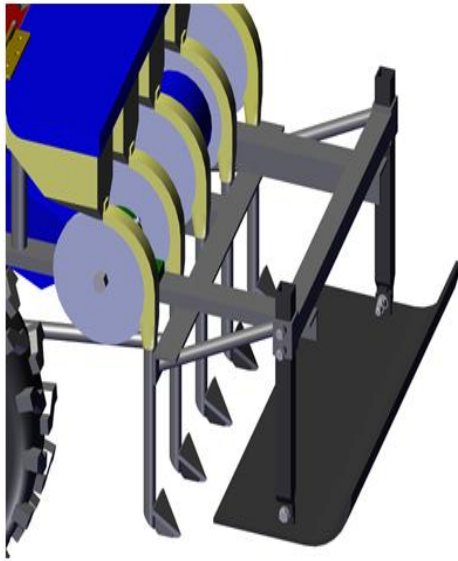


Fig. 8. Skid of the seeder

## 5. CONCLUSION

A carrot seeder was successfully designed and simulated based on the needs of the farmers. The design consisted of 5 metering discs corresponding to 4 rows in a plant bed which is the usual practice of the farmers. A pair of ground wheels with diameter of 40 cm which are commercially available were also utilized in the design. The size of the wheels also suits the requirement for the spacing between the plant beds and the height of the plant bed. The problems of other designs were addressed in the concept design and this design is recommended for fabrication for actual field testing. Initial activities are also underway towards the commercialization of the seeder design by means Freedom To Operate and Intellectual Patent Valuation in addition to licensing an accredited agricultural machinery fabricator.

## DISCLAIMER

The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

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## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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