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Development of a Machine for Planting Faba Bean

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Abstract

Faba bean (*Vicia faba L.)* is an important legume crop and is mainly grown for human and animal consumption as food. The aim of this research is to develop and evaluate a faba bean seeder. The developed seeder machine consists of the main frame with three hitching points, seed box, fertilizer box, six vertical rollers with round cells metering device, six plastic seed tubes, six plastic fertilize tubes, six shovel furrow openers ,six chain covering device and three diggers. Laboratory experiments were carried out as a function of change in metering device speed and cells size (1 seed/cell and 2seed/cell). While, field experiments were conducted to optimize machine forward speed and planting depth. The machine performance was studied in terms of seed damage, plant scattering, emergence, crop yield, specific energy and planting cost. The experimental results revealed that the developed faba bean planter is recommended to be used under the following conditions: forward speed of 3.5 km/h and cells size of 2seed/cell at planting depth of 50 mm. The obtained results at optimum conditions were: plant emergence of 97.70%, seed yield 3.99 ton/ha, ground wheel slip of 3.9 %, required power of 4.04 kW, specific energy of 8.66 kW h/ha, field capacity of 0.47 ha/h, operational cost of 9.54$/ha.

Keywords: Faba bean crop, *Vicia faba L.*, planter, metering device and cultivating methods.

INTRODUCTION

The faba bean (*Vicia faba L.*) is one of the world's most important legume crops. Faba beans are high in protein, making them extremely nutritious, as well as a good source of minerals, vitamins, nutrients, and a variety of bioactive substances. In 2014, faba bean grain production totaled 4.1 million tons, an increase of roughly 21% over 1994 **(FAO, 2017).**

Beans (*Vicia faba l.)* are the most widely cultivated legume crop in Egypt, with the highest cultivated area, total production, and consumption. Beans (*Vicia faba l.)* are consumed as processed food by humans because they contain a high quality percentage of carbohydrates (58%) and protein (28%) as well as many other vitamins and nutrients. Egypt has the highest bean productivity in the Mediterranean region, with an average cultivated area of 86.1 hectares per year and an average yield of 4.47 tons per hectare **(Ministry of Agriculture, 2019).**

Ibrahim *et al.* (2008) developed a seed drill technique for planting rows of soaked and hasted seed rice. The results revealed a drop in weed plants per square meter and a 97 percent rise in germination percent at a forward speed of 0.64 m/s.

To improve planting productivity and reduce drudgery, **Kyada and Patel (2014)** devised and built a manually operated template row planter. Seeds of varying sizes can be planted at varied depths and with varying spacing between them. It also increased seed planting and seed/fertilizer placement precision, and it was made of a durable, low-cost material that peasant farmers could purchase. Working, adapting, and retaining ideas were simplified to make them easier to handle for untrained operators.

Adekanye (2015) used a meteringunit planter. For cowpea, maize, and soybean seed rates of 0.25 kg/ha, 0.18 kg/ha, and 0.21 kg/ha, the planter had a field productivity and field ability of 76.3 percent and 0.39 ha/h, respectively. Seed damage of cowpea, maize, and soybean was 3.54 percent, 2.32 percent, and 1.32 percent, respectively, with an average spacing of 400.8 mm and a depth of 30.98 mm.

Ani, *et al.* (2016) designed, constructed, and tested a low-cost, manual-operated maize planter for seed drilling. The seed metering equipment is linked to a delivery mechanism (vertical shaft) that transports the seeds to their final location. The effective field capacity in the field test was 0.128 ha/h, with a field efficiency of 76.5 percent. The seed-metering device in another design is a wooden roller with compartments around the perimeter. The seed size and seed rate determine the size and number of cells on the roller. The seeds are lifted into the cells by the wooden roller and dropped into the seed funnel, which is then delivered to the open groove via the seed tube.

Prajaiah *et al.* (2016) assessed the effect of levels of variables such as forward speed, cell shape, and seed metering performance characteristics on three seed-metering systems. For all metering plates evaluated, mean seed spacing, miss index, and seed damage increased as forward speed increased, but multiple index reduced as forward speed increased. The average seed spacing was 140.8 mm, which was close to the theoretical seed spacing of 150 mm. The greatest quality feed index was 1%, the lowest miss index was 6.1 percent, and the seed damage was 0.38 percent.

The main frame, seed hopper, seed metering mechanism, drive wheels, seed tube, furrow opener, furrow closer, and push handle were all designed and evaluated by **Omran (2018)** for a manually row planter for field crop seeds. The designed machine had a high field capacity of 7.6 and 10.2 times for maize sowing at 1.89 and 2.61 km/h forward speeds, and 8.9 and 11.9 times for faba bean sowing at 1.83 and 2.58 km/h forward speeds, respectively, and the amount of seeds per hectare was reduced by 40 and 11.5 percent for maize and faba bean, respectively, when compared to manual planting. Under the two available speeds, the total cost of planted hectare by the single row planter was 95.92 & 96.63 percent and 89.35 & 89.84 percent cheaper than hand planting for maize and faba bean, respectively.

Due to a shortage of hand labours in Egypt and rising wages, which resulted in higher production costs and late crop planting on the dates of subsequent cultivation, which had a negative impact on productivity, a machine was developed to cultivate the municipal saying in a hill on lines of varying distances. The following are the goals of this investigation:

- Create a seeder machine out of local materials that can be used to plant faba bean seeds.

-Optimize a few different operations that have an impact on the developed seeder's performance.

-Evaluate the seeder machine from the costs point of view.

MATERIALS AND METHODS

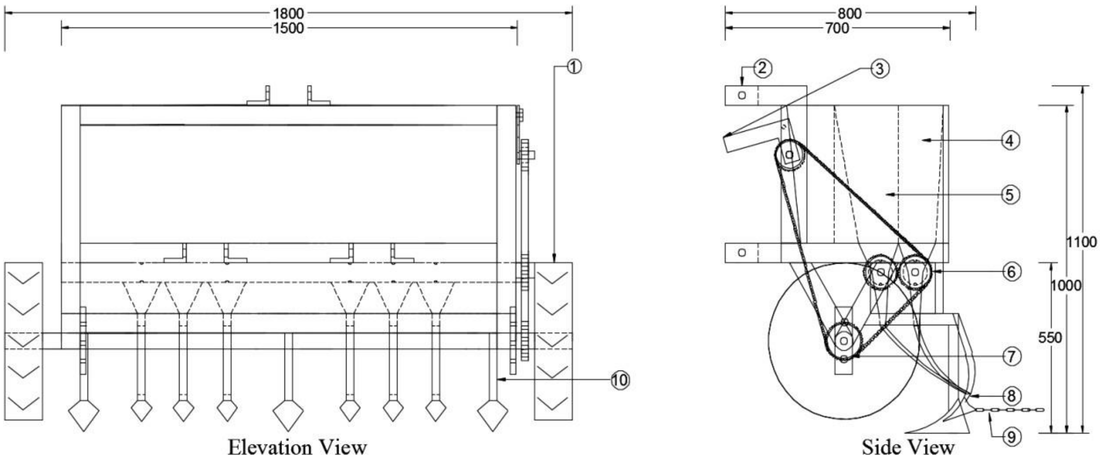
Materials:

Developed faba bean seeder: The developed faba bean seeder as shown in Fig. 1 consists of the main frame with three hitching points, seed box, fertilizer box, six vertical rollers with round cells metering device, six plastic seed tubes, six plastic fertilize tubes, six shovel furrow openers ,six chain covering device and three ridgers. It has dimensions 1800 mm in length, 800 mm in width and 1100 mm in height and its mass is about 350 kg.

The developed faba bean seeder consists of the following parts:

-Frame: The structure is made of sheet iron and iron corners with dimensions of 500 x 500 x 50 mm. The overall dimensions of the upgraded faba bean seeder are 1800 mm in length, 800 mm in width and 650 mm in height.

-Box: it was divided into two parts: Part No. 1 is a seed box, Part No. 2, is about the NPK fertilizer box during planting. All parts of the box are built of steel sheets 3 mm thick, with dimensions of 1500 x 500 x 450 mm and a bottom inclined 60 degrees.



No.	Part name	No.	Part name	No.	Part name	No.	Part name
1	Ground wheels	4	Seed box	7	Graduated ruler	10	Ridger
2	Hitching points	5	fertilizer box	8	Seed tube		
3	Tensioner gear	6	Metering device	9	Covering device		

Dims.in mm

Fig.1. Schematic views of the developed faba bean seeder.

- Seed metering device:

The seed metering consists of vertical roller with round cells, gate, a cleaning brush, housing and cover. The plastic roller is a diameter of 100 mm and width of 30 mm. Fig. 2 showed isometric of the metering device parts: Vertical roller with cells, Bruch, Gate, Housing and Cover.

-A cleaning brush: brush was attached on top of the seed roller to wipe away any extra seeds in the cells. It is made of rubber, 5 mm thick and 30 mm wide. Under a square gate whose dimensions are 15 x 15 mm.

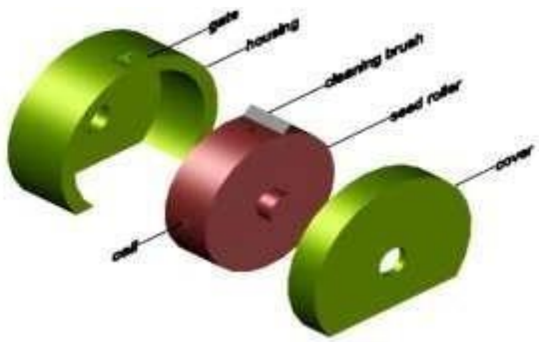
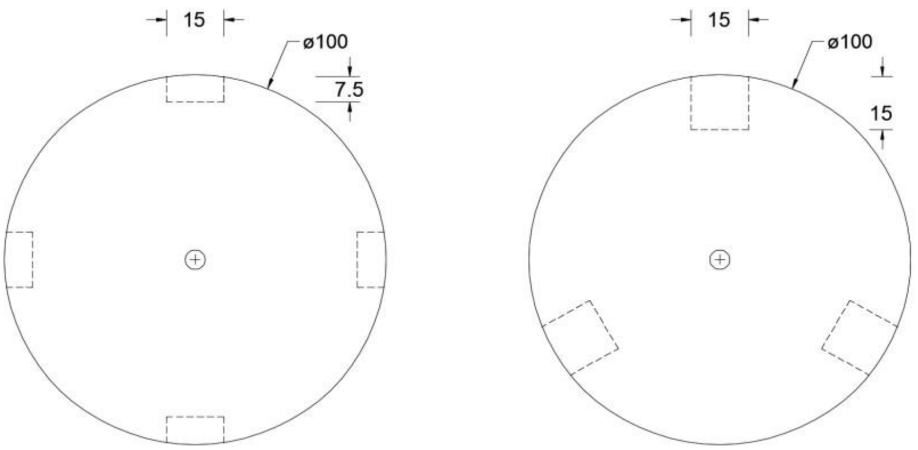


Fig.2. Isometric of metering device parts

-Vertical roller: It has two kind of vertical roller. The first kind has four round cells with cells size 1seed/cell (for cultivate in three rows on line with 150 mm longitudinal distances between hills) and the second round kind has three round cells with cells size 2 seed/cell (for cultivate in two rows on line with 200 mm longitudinal distances between hills).The round cell has with diameters of 15 mm and tested cell depth of 15 and 7.5 mm respectively. Fig.3 shows Isometric for different vertical roller with different cells size.



(a) **(b)**

Dims.in mm

Fig.3. The vertical rollers with different cells size. **(a)**1seed/cell **(b)** 2seed/cell

-Seed tube: The seed tubes were made of plastic with a diameter of 50 mm, a length of 600 mm and a thickness of 2 mm.

-Ridger: it consists of share with width dimensions of 300 mm.

-Covering device: It consists of four iron rings with diameter of 150 mm.

-Graduated ruler: There are three points on it to control the depth of cultivate and putted on the axle of the wheels.

-Tractor: A 30 hp (22.4 kW) Kubota tractor (Model: L295) was used as the power source to power the upgraded machine.

-Faba bean seeds: Physical and mechanical properties of faba bean seeds are shown in Table 1. These data were measured for seeds sample according to the standards set by "Mohsinin, 1986".

Table 1: Physical and mechanical properties of faba bean seeds.

Property	Mean value	Standard errors
kind	Misr 1	0.0
Moisture content (% d.b.)	9.8	0.2
Length (mm)	13.55	0.14
Width (mm)	10.69	0.21
Thickness (mm)	6.09	0.16
Arithmetic mean diameter (mm)	10.18	0.12
Geometric mean diameter (mm)	9.69	0.08
Sphericity (%)	66.52	0.17
Static coefficient of friction with iron (m)	0.29	0.02
Thousand seeds mass (g)	625.4	0.18
True density (kg m^{-3})	1094	0.22
Bulk density (kg m^{-3})	825	0.09
Porosity (%)	27.89	0.15
Angle of repose(^{o})	29.68	0.93

Sample Preparation

Faba bean was planted in the field of Zagazig center, Sharkia Governorate, Egypt (30° 34' N Latitude, 31° 30' E Longitude(. All seeds obtained from the crop were cleaned manually by sieve and with fresh water to remove all foreign matter.

Methods

Two experiment groups were carried out on the effect of some factors on the developed faba bean planter performance as follows:

1- Laboratory experiments: They were carried out to find the factors affecting seed discharge, seed damage and germination. These factors are: metering device speed and cell size (number of seed per cell). All treatments were replicated six times to give more reliable averages.

2- Field experiments: they were carried out to determine the following points: emergence percentage, longitudinal seed distribution, slip of ground wheel, fuel consumption, power, specific energy, field capacity, crop yield, and estimating the costs of using the machine.

Planting intensity ranges were 119- 142.8 kg seeds/ha, 200 mm longitudinal distances between hills for 2seeds per cell to planting in two rows on line or 150 mm longitudinal distances between hills for 1seed per cell to planting in three rows on line and 600 mm between rows. (According to recommendation of Field Crops Research Institute, Ministry of Agriculture) The planting intensity was varied according to number of seed per cell and forward speed.

Tested parameters:

Metering device speed: six metering device speeds of 20, 40, 60, 80, 100 and120 rpm (0.1, 0.2, 0.3, 0.4, 0.5 and 0.6 m/s) or ground speeds of 10, 20, 30, 40, 50 and 60 rpm (0.2, 0.4, 0.6, 0.8, 1.0 and 1.2 m/s) were tested in laboratory.

Cell size: two cell sizes of 1seed/cell(for planting in three rows on line with 150mm longitudinal distances between hills) named C1 and 2seed/cell (for planting in two rows on line with 200 mm longitudinal distances between hills) named C2 were tested in laboratory and field.

Forward speed: Four forward speeds of 2.5, 3.5, 4.5 and 5.5 km/h were tested in the field.

Planting depth: Three depths of 20, 50 and 80 mm were tested in the field.

Measurements:

- Seed discharge: Seed discharge was measured in laboratory and field tests at different ground wheel speeds of 10, 20, 30, 40, 50and 60 rpm or metering device speeds of 20, 40, 60, 80, 100and 120 rpm cell size (1and2seed/cell(and forward speeds of 2.5, 3.5, 4.5 and 5.5 km/h. The discharge seeds were collected in plastic bags during a certain number of ground wheel revolutions.

- Seed damage and germination: In the previously mentioned factors, the damaged seeds were counted manually and weighed. The percentage of seed damage were calculated, and related to the seed discharge. One hundred faba bean seeds were germinated laboratory to give the germination percent before passing through the metering device.

The actual germination percent of seeds after passing through the metering device was calculated by the following equations (**Yehia, 1997**):

Actual germination percent = Germination % of unused seeds - (Visible seed-damage, % + invisible seed damage, %)

$$\text{Visible seed-damage, \%} = \frac{\text{Mass of damaged seed}}{\text{Total mass of seed}} \times 100$$

Invisible seed damage, % = (No. of shoots / Total No. of seeds) x 100

- Emergence percentage: The number of plants per meter of the row was counted for the four tested forward speeds of 2.5, 3.5, 4.5 and 5.5 km/h, two cell size and three planting depth to determine the emergence percentage according to the following formula:

$$\text{Emergence percentage} = \frac{\text{Germinated seeds}}{\text{Total seeds}} \times 100$$

- Plant scattering: For forward speeds, the faba bean seed plants were counted to determine the longitudinal plant distribution at different previously mentioned factors.

The plant distribution was analyzed to determine coefficient of variation (CV) of seeds spacing according to the following formula:

$$\text{CV, \%} = \frac{\text{SD of plant spacing}}{\text{Recommended plant spacing}} \times 100$$

Where: SD is the standard deviation.

SD =√ (Plant spacing - Recommended plant spacing) ^{2}

The coefficient of variation less than 10% is considered excellent and with value less than 20% is considered acceptable for most field applications as stated by (Coates, 1992).

- Missing hill percentage: The missing hill percentage was calculated according to the following equation (**Grewal, 2014**):

$$\text{Missing hills, \%} = \frac{\text{Number of missing plants per m}^2}{\text{Total plants per m}^2} \times 100$$

- Slip of ground wheel: Slip of ground wheel is an important factor that affects sowing rate per area. The percentages of slip were estimated for four forward speeds. Slippage percentage was calculated by using the following formula (**Awady, 1992**).

$$\text{Slippage, \%} = \frac{\text{Actual distance - Theoretical distance}}{\text{Theoretical distance}} \times 100$$

Where: Theoretical distance = No. of wheel revolutions x π wheel diameter.

- Total and faba bean yield: The total and yield of each plot was measured to study the effect of the above mentioned factors on faba bean crop. A frame of 1 x 1 m^2 was used for measuring the yield. The yield of the crop located within the frame was measured. The average total yield was calculated for all treatments in (ton/ha).

- Theoretical field capacity: It was determined using the following equation:

$F.C._{th}$, ha/h = S x W / 10000

Where: F.C.th: Theoretical field capacity, ha/h., S: machine forward speed, m/h. and W: machine width, m.

-Actual field capacity: It was calculated using the following equation:

$F.C._{act}$, ha/h = 60 / Tu + Ti

Where: $F.C._{act}$: The actual capacity of the machine, ha/h, Tu: The utilized time per ha, min. and Ti: The summation of time lost per ha, min.

-Field efficiency: It was calculated using the following equation:

ηf ,% = $F.C._{act}$ / $F.C._{th}$ × 100

Where: ηf = Filed efficiency, %, F.C.act. = Actual field capacity, ha/h and F.C.th. = Theoretical field capacity, ha /h.

- Fuel consumption: Fuel consumption per unit time was determined using a calibrated tank (refilling method) to measure the volume of fuel consumed during the operation time.

- Required power: The following formula was used to estimate the required power (Donnell, 1983):

RP = 3.16 x fc

Where: RP is the required power, kW; fc is the fuel consumption, l/h.

- Specific energy: It can be calculated by using the following equation:

$$\text{Specific energy, kW h/ha} = \frac{\text{Power required, kW}}{\text{Actual field capacity, fed/h}} \times 100$$

- Estimation cost: The hourly cost was calculated according to equation of (**Awady, 1978**) in the following form:

$$C = P/h\,[\,1/a + i/2 + t + r\,] + (1.2 \times w \times f \times s) + m/144$$

Where:

C = Hourly cost, \$/h.

P = Price of machine, \$

h = Yearly working hours, h/year.

a = Life expectancy of the machine, year.

i = Interest rate/year.

f = Fuel price, \$/l.

t = Taxes, over heads ratio.

r = Repairs and maintenance ratio.

m = Monthly average wage, \$

1.2 = Factor accounting for lubrications.

w = Engine power, hp.

s = Specific fuel consumption, l/hp.h.

144 = Reasonable estimation of monthly working hours.

Operational cost can be determined using the following equation:

$$\text{Operational cost, \$/fed} = \frac{\text{Hourly cost, \$/h}}{\text{Actual field capacity, ha/h}}$$

Cost per unit of production can be determined using the following equation:

$$\text{Cost per unit of production, \$ /ton} = \frac{\text{Operational cost, \$/ha}}{\text{Crop yield, ton /ha}}$$

RESULTS AND DISCUSSION

1. Results of laboratory experiments:

Laboratory experiments were carried out to study the effect of metering device (ground wheel) speed on the performance of the developed faba bean seeder. Laboratory experiments help to adjust the seeder machine under the optimum conditions during the field experiments.

1.1. Effect of metering device speed and cells size on seed discharge

Fig. 4 shows the effect of metering device speed and cell size on faba bean seed discharge and seeding rate. Results showed that seeding rate decreased by increasing metering device speed and increased by increasing cell size. The maximum seed discharges of 165.3 kg/ha revolutions of metering device were obtained at metering device speed of 20 rpm and cell size of 2seed/cell. Meanwhile, the minimum seed discharges of 95.8 kg/ha revolutions of metering device were obtained at metering device speed of 120 rpm and cell size of 1 seed/cell.

The decreasing of faba bean discharge by increasing metering device speed is due to the time is not enough to fill all cells of metering device by seeds. While increasing seeds discharge by increasing cell size may be due to increasing the volume and faced area of metering device cell under the seed box opening gate.

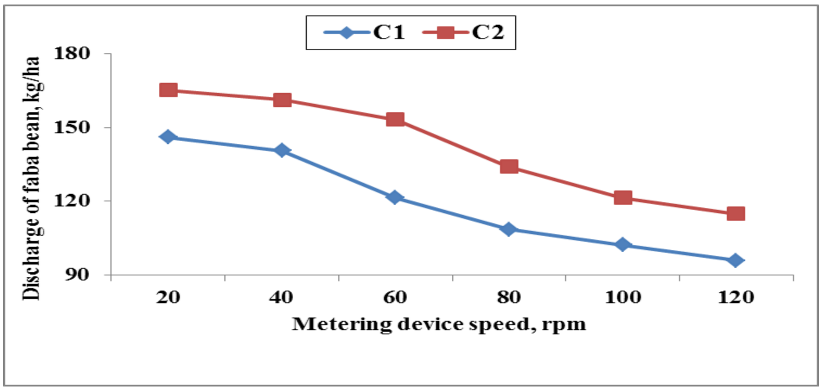


Fig.4. Effect of metering device speed and cells size on seed discharge

1.2. Effect of metering device speed and cells size on seed damage percent

Fig. 5 shows the effect of metering device speed and cell size on seed damage percent. Results showed that seed damage decreased by increasing cell size and increased by increasing metering device speed. The maximum seed damages of 4.78 and 4.16 % were obtained at metering device speed of 120 rpm for cell size of 1 seed/cell and 2 seed/cell respectively. Meanwhile, the minimum seed damages of 1.7 and 1.32 % were obtained at metering device speed of 20 rpm for cell size of 1 seed/cell and 2 seed/cell respectively.

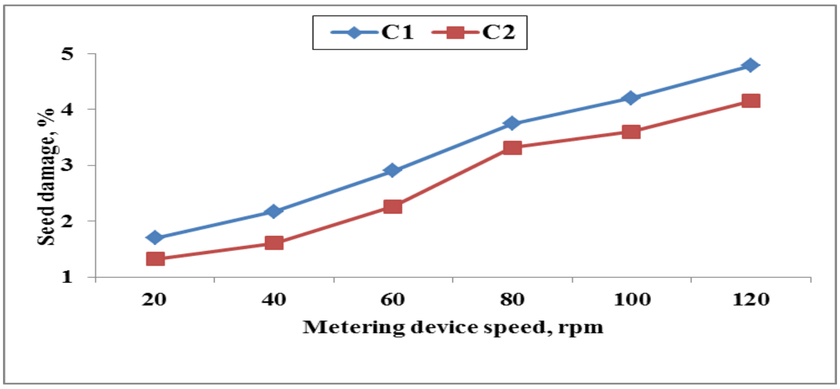


Fig.5. Effect of metering device speed and cells size on seed damage percent

1.3. Effect of metering device speed and cells size on germination percent

Fig. 6 illustrates the germination percent using different values of metering device speed and cells size. Results showed that faba bean seed germination decreased by increasing metering device speed and decreasing of cell size. The maximum seed germination of 97.3 and 97.68 % were obtained at metering device speed of 20 rpm for cell size of 1 seed/cell and 2 seed/cell respectively. Meanwhile, the minimum faba bean seed germination of 94.22 and 94.84 % were obtained at metering device speed of 120 rpm for cell size of 1 seed/cell and 2 seed/cell respectively.

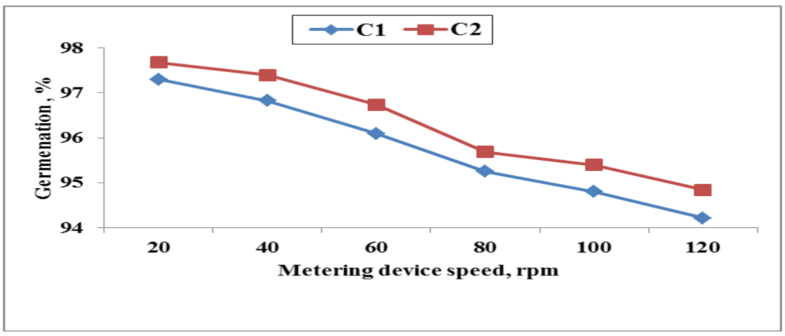


Fig.6. Effect of metering device speed and cells size on germination percent

2. Results of field experiments:

2.1. Effect of forward speed, cells size and cultivating depth on seeding rate

Fig. 7 shows the effect of forward speed, cells size and planting depth on faba bean seeding rate. Results showed that seeding rate increased by decreasing of forward speed, increasing of cells size and increasing cultivating depth. The maximum seeding rate of 157.18, 161.98 and 166.72 kg/ha was obtained at forward speed of 2.5 km/h and cells size of 2seed/cell for planting depths of 20, 50 and 80 mm respectively. Meanwhile, the minimum seeding rate of 95.8, 98.9 and 103.69 kg/ha were obtained at forward speed of 5.5 km/h and cells size of 1seed/cell for cultivating depths of 20, 50 and 80 mm respectively. The decreasing of seeding rate of field experiments compared with laboratory experiments is due to ground wheel slip.

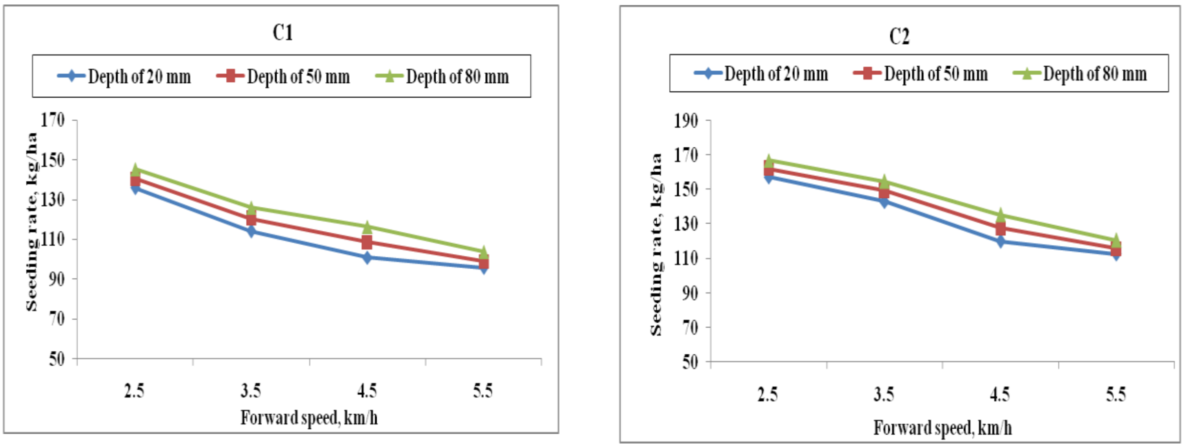


Fig.7. Effect of forward speed, cells size and planting depth on seeding rate

2.2. Effect of forward speed, cells size and planting depth on emergence percent

Fig. 8 shows the effect of forward speed, cells size and planting depth on the emergence percentage of faba bean seed. Results showed that plant emergence decreased by increasing forward speed, decreasing cell size and decreasing planting depth from 50 to20 mm and increase from 50 to 80 mm. The maximum faba bean plant emergences of 98.27 % were obtained at forward speed of 2.5 km/h and cell size of 2seed/cell with cultivating depth of 50 mm. Meanwhile, the minimum faba bean-plant emergence of 94.49 % was obtained at forward speed of 5.5 km/hand cell size of 1 seed/cell with cultivating depth of 20 mm. The decrease of plant emergence by increasing forward speed is due to the increase of metering device speed and the momentum of seeds which causes seed damage accordingly. Also, planting depth could not be thoroughly adjusted at high speed that tends to decrease plant emergence.

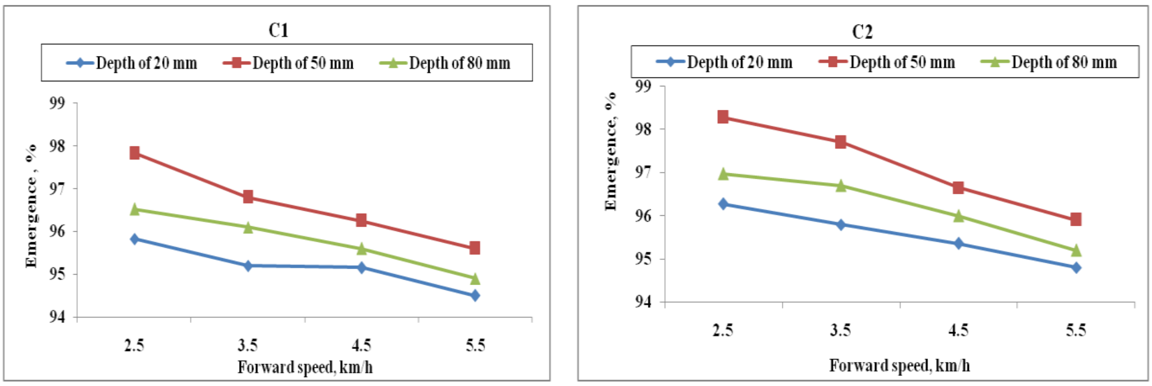


Fig.8. Effect of forward speed, cells size and planting depth on the emergence percent

2.3. Effect of forward speed, cells size and planting depth on plant scattering

The plants distribution was analyzed in order to determine the coefficient of variation (CV) of plant spacing. A low CV represents a row with more uniform seed spacing, while the vice versa was noticed with high values of CV. The plant scattering for different cutoff clearances and forward speeds were illustrated in Fig. 9. The optimum conditions clarify that the forward speed of 2.5 km/h and cells cell size of 2seed/cell with cultivating depth of 20, 50 and 80 mm respectively had the best longitudinal distribution (CV of 3.10, 2.50 and 2.20 %). The increase of plant scattering by increasing forward speed may be due to increasing the machine vibration and ground wheel slip. Meanwhile, the decrease of plant scattering by increasing cells size may be due to decreasing the missing hills.

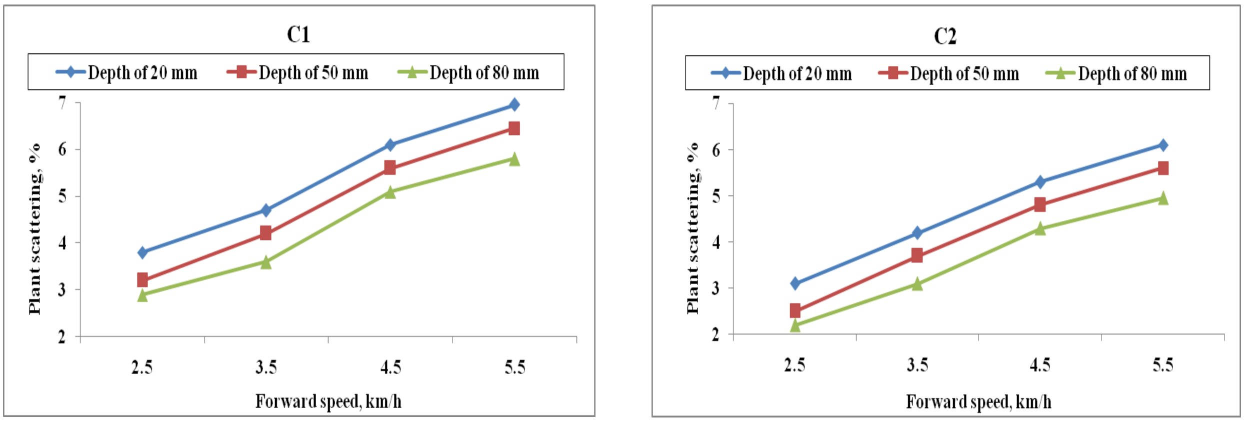


Fig.9. Effect of forward speed, cells size and planting depth on plant scattering

2.4. Effect of forward speed, cells size and planting depth on missing hills percent

Fig. 10 illustrates the on missing hill percent in the field using different values of forward speed, cells size and planting depth. Missing hills increased with increasing forward speed, decreased cells size with different depth. Results Show that increasing forward speed from 2.5 to 5.5 km/h, increased missing hills from 2.67 to 5.44 % and from 1.67 to 4.54 % at depth of 50 mm for cells size 1seed/cell and 2seed/cell, respectively. The increase of missing hills by increasing forward speed may be due to increasing the machine vibration and ground wheel slip.

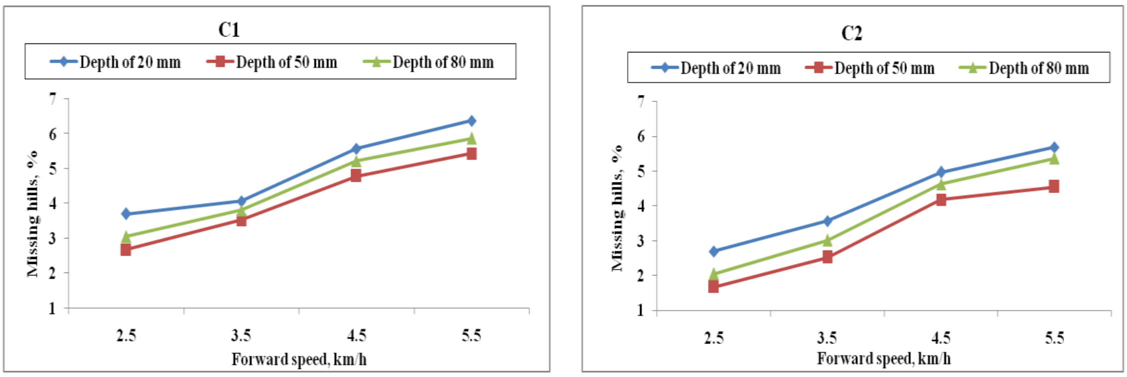


Fig.10. Effect of forward speed, cells size and planting depth on missing hill percent

2.5. Effect of forward speed, cells size and planting depth on faba bean yield

Fig. 11 shows the effect of forward speed, cells size and planting depth on faba bean yield. The yield decreased by increasing forward speed, decreasing cell size and decreasing cultivating depth. The maximum faba bean yields of 4 and 4.12 ton/ha was obtained at forward speed of 2.5 km/h and cell size of 1 seed/hill and 2 seed/hill with depth of 50mm, respectively. Meanwhile, the minimum seed yields of 3.14 and 3.4 ton/ha were obtained forward speed of 5.5 km/h and cell size of 1 seed/hill and 2 seed/hill with depth of 20mm, respectively. The decrease in seed yield by increasing forward speed is due to the low plant emergence resulting from ground wheel slip at high speed. Also due to seed damage occurred by the effect of the metering device.

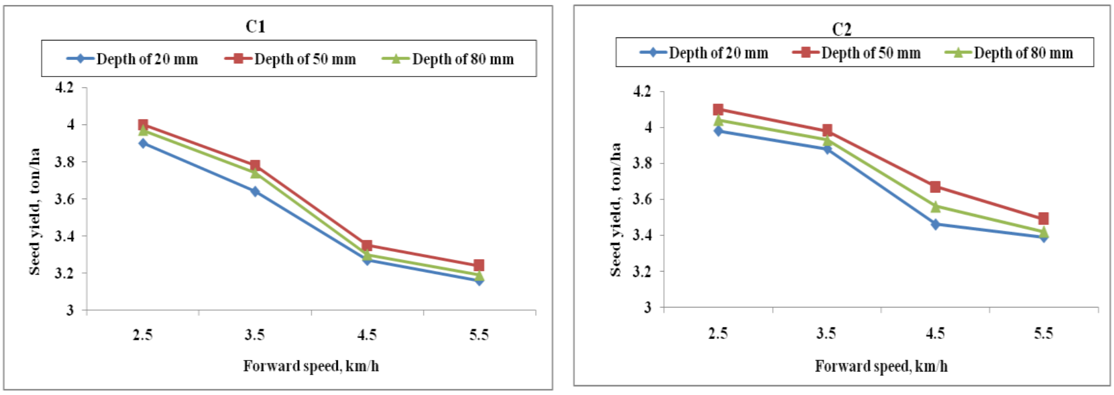


Fig.11. Effect of forward speed, cells size and planting depth on faba bean yield

2.6. Effect of forward speed, cells size and planting depth on machine field capacity, efficiency and wheel slip

Fig. 12 shows the effect of forward speed on actual field capacity, field efficiency and slip percent. The maximum actual field capacity of 0.66 ha/h was obtained with forward speed of 5.5 km/h. Meanwhile, the minimum actual field capacity of 0.35 ha/h was obtained with forward speed of 2.5 km/h. The maximum field efficiency of 87.97 % was obtained with forward speed of 2.5 km/h. Meanwhile, the minimum field efficiency of 77.33% was obtained with forward speed of 5.5 km/h. The slip percent of press wheel increased with increasing forward speed. The maximum slip of 5.7 % was obtained with forward speed of 5.5 km/h. Meanwhile the minimum slip of 3.5 % was obtained with forward speed of 2.5 km/h.

2.7. Effect of forward speed on fuel consumption, required power and specific energy

Fig. 13 shows the effect of forward speed on required power and specific energy. The maximum required power and specific energy of 8.37 kW and 12.38 kW h/ha were obtained withforward speed of 5.5 km/h. Meanwhile the minimum values of 2.46 kW and 7.11 kW h/ha were obtained with forward speed of 2.5 km/h.

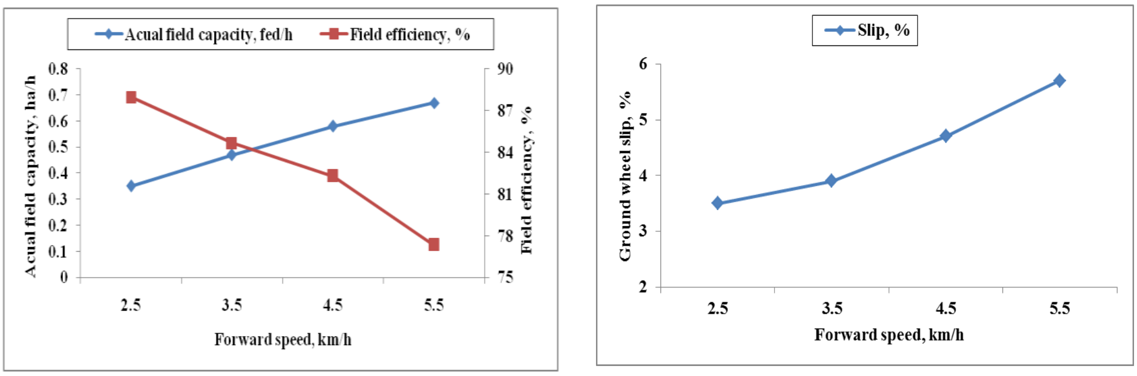


Fig.12. Effect of forward speed on actual field capacity, field efficiency and slip percent

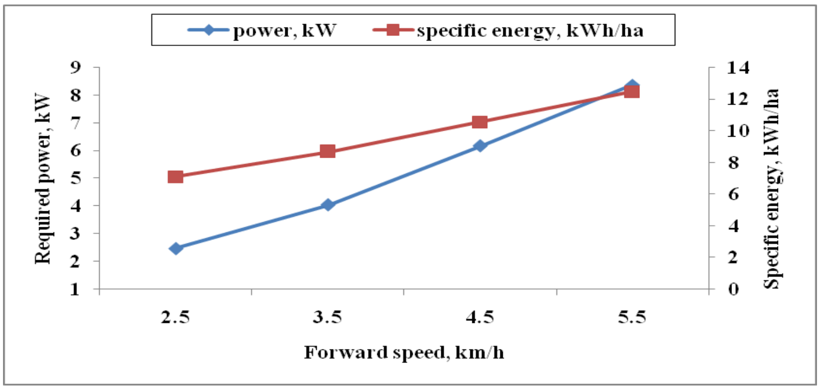


Fig.13. Effect of forward speed on required power and specific energy

Table 2: Operational cost and operational cost for product 1ton of using the developed faba bean planter at different values of forward speeds, cells size and planting depth.

Cell size	Forward speed, km/h	Hourly cost, $/h	Operational cost, $/ha	operational cost for product 1ton, $/ton		
				Planting depth, mm		
				20	50	80
C1(1 seed/cell)	2.5	4.2	12.51	3.1	2.99	3.0
	3.5	4.46	9.54	2.62	2.53	2.55
	4.5	4.76	8.15	2.49	2.44	2.47
	5.5	5.0	7.47	2.36	2.3	2.34
C2(2 seed/cell)	2.5	4.2	12.51	3.05	2.95	3.0
	3.5	4.46	9.54	2.46	2.39	2.42
	4.5	4.76	8.15	2.36	2.22	2.29
	5.5	5.0	7.47	2.2	2.14	2.18

2.8. Operational cost and operational cost for product 1ton of using the faba bean seeder machine

Table 2 shows operational cost and operational cost for product 1ton of using the developed faba bean seeder at different values of forward speeds, cells size and cultivating depth. The operational cost decreased by increasing forward speed. The minimum operational cost and operational cost for product 1ton of 7.47 $/ha and 2.3 $/ton were obtained using the developed faba bean seed planter with forward speed of 5.5 km/h, cell size 2 seed/cell for depth 50 mm. Meanwhile, The maximum operational cost and operational cost for product 1ton of 12.51 $/ha and 3.1 $/ton were obtained using the developed faba bean seeder with forward speed of 2.5 km/h, cell size 1 seed/cell for depth 20 mm. The cost of manual faba bean planting was 95.2 $/ha.

CONCLUSION

It was recommended to use the developed faba bean seed planter under the following optimum conditions:

-Forward speed of 3.5 km/h, cell size of 2 seed/cell (for cultivate in two rows on line with 200 mm longitudinal distances between hills), and Using cultivating depth of 50 mm.

The obtained results at optimum conditions were: plant emergence of 97.70%, seed yield 3.99 ton/ha, ground wheel slip of 3.9 %, required power of 4.04 kW, specific energy of 8.66 kW h/ha, field capacity of 0.47 ha/h, operational cost of 9.54 $/ha.

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