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Development and Evaluation of A Carrot Seeder

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ABSTRACT

The main objective of the present investigation is to develop and evaluate the performance of a carrot seeder with 12 vertical rollers with cells metering, The performance of the developed seeder was experimentally investigated in the laboratory under seven metering-device speeds ranged between 20 to 140 rpm and three cell-sizes of 1, 2 and 3 seed/cell and tested in the field with uncoated and coated seeds under four forward speeds 2, 3, 4 and 5 km/h. The main results of this study can be summarized in the following points: The maximum seeding rates of 2.218 and 7.863 kg/fed were obtained at metering speed of 20 rpm (ground-wheel speed of 10 rpm) and cell size of 3 seed/cell using uncoated and coated seeds, respectively. Meanwhile, the minimum seeding rates of 0.462 and 2.097 kg/fed were obtained at metering speed of 140 rpm (ground-wheel speed of 70 rpm) and cell size of 1 seed/cell for uncoated and coated seeds, respectively. The maximum carrot-plant emergences of 95.11 and 97.15 % were obtained at forward speed of 2 km/h and cell size of 3 seed/cell using uncoated and coated seeds, respectively. Meanwhile, the minimum carrot-plant emergences of 92.01 and 94.22 % were obtained at forward speed of 5 km/h and cell size of 1 seed/cell for uncoated and coated seeds, respectively. The maximum carrot-fruit yields of 13.11 and 18.62 Mg/fed were obtained at forward speed of 2 km/h and cell size of 3 seed/cell for uncoated and coated seeds, respectively.

Keywords: Carrot, seeder, emergences

INTRODUCTION

Precision placement of small seeds of vegetable like carrot need a labor intensive, time consuming and difficult operation. It is difficult to obtain regular seed-rate of such small seed. To increase production, productivity and to reduce production cost, mechanized planting are required which will ensure uniformity and timeliness of carrot planting. Mechanical precision-planting of small seeds of vegetables like carrot is very difficult and consumes more time. Information about design, development and evaluation of carrot seeders is scarcely available.

The principle of any planting operation is to stablish an optimum plant population and spacing to obtain the maximum net profit per feddan. Plant spacing effect on the cost of thinning, weed control, inter-row cultivation and harvesting.

Carrot is an important root vegetable crop over 150 countries throughout the world. The cultivated area in Egypt in year of 2019 (17.831 thousand feddans) and the fruit production is 235.191 thousand Mg/year (FAO, In references 2019). Carrot has an excellent source of antioxidants which protect against cardiovascular disease and cancer and promote good vision especially at night. Carrots are also beneficial for the heart, blood circulation, eye sight, skin and lungs (Singh *et al*., 2006). Low level of carrot planting and harvesting mechanization is a major hindrance in increasing the production of carrot. The traditional method of carrot planting by seed broadcasting and dibbling in depth of 2 – 3 cm with row spacing of 15 – 20 cm. Manual seedling needs intensive labors and high operation cost. Precision planting enables the proper seed placement in a row, row spacing and depth. A uniform mechanized planting saves seed, increases nutrients utilizing, decreases plants competition which increases carrot production-profit.

Certain limitations are associated with the production, processing and effective utilization of small seeds. Many vegetable seeds are small, light and irregular in shape; therefore it is difficult to plant them precisely (Tuna and Zeybek, 2009). Sowing of such tiny size, light weight and irregular shaped seeds are generally accomplished manually using broadcasting method. There is little control over the seed placement, spacing, line sowing, the plant stand is uneven and requires good management. A large amount of costly seed may get wasted because of uneven seed placement, thinning, damage by seed metering mechanism, damage by birds. Seed pelleting is an essential component of seed technology and plays vital role in making the seed bolder, safer in handling and in field emergence. The pelleting is designed basically to facilitate accurate precise sowing, to protect the seed against soaking injury, to excess soil moisture and to give at least as good seedling emergence as does raw seed (Powell and Mathews, 1988). Seed size of carrot seeds is very small making singularization and precision placement difficult. Moreover, seeds should be protected from a range of pests that attack seedlings. Seed-coating technologies can be employed for two purposes: they can facilitate mechanical sowing to achieve uniformity of plant spacing, and can act as a carrier for plant protectants. Gautam *et al.* (2016) studied physical and engineering properties of carrot seed. Both un-pelleted and pelleted were evaluated in the laboratory. It was found that the geometric mean diameter (GMD) was 2.03, 2.19, 2.39 and 2.70 mm for deshi red carrot seeds. Using coating materials Fe + Zn +Arasan gave the best result of

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germination of pepper seeds of 98.5 % compared to untreated seeds which has a germination of 62.8 % (Abd El Fattah 2016).

Yadachi (2011) designed and evaluated a seed-carrot planter. The studied parameters were cell shape (semi-circular, triangle and slant), metering disc incline-angle (40, 50 and 60 degree) and seed treatment (uncoated, biogas slurry coated and Thirame coated). .The optimum conditions were disc angle of 50^0, slant cell shape which gave the best feed index of 83.9 %, least miss and multiple indices of 6.11 %. The optimum plant population per meter length of row of 72 which obtained with biogas slurry coated seeds (theoretical plant population was 80/m row length) and yield of 20.14 Mg/ha. Gautam *et. al.* (2019) designed and evaluated of inclined plate metering device for coated carrot-seeds. The designed metering device was tested in the laboratory for the treated seeds which pelleted in the ratio of 1:1, 1:2 and 1:3, using different developed seed plates having 18, 24 and 30 grooves at forward speeds of 1.0, 2.0 and 3.0 km h^{-1} and inclination angle 40°, 45° and 50°. Average seed spacing obtained at in 1:3 seed, 45° angle and forward speed 2.0 km h^{-1}, the average spacing was observed to be 4.48, 4.29 and 4.11 cm for 18, 24 and 30 groove plate respectively. Missing index at 2.0 km h-1 forward speed with 24 groove seed metering plate with 45^o inclination angle was 5.0 % and multiple index was 14.0 %. Valentin (2016) developed and evaluated a push carrot-seed seeder. Results of evaluation showed that the performance of the newly developed carrot seeder was optimum at a forward speed of 1.0 m/s with a dropping efficiency of 96.7%, coefficient of variation of 1.7%, field efficiency of 88.2%, germination of 82.3%, and average number of seeds deposited of 2.5. The device was also found to be 76% faster than the conventional method of planting carrot seeds. Islam *et al*. (2015) evaluated the effect of number of plant per hill and irrigation intervals on the growth and yield of carrot. There were three levels of number of plant per hill viz. 1, 2 and 3 plants per hill and four irrigation intervals (I0 = No irrigation after germination, I1 = 14 days, I2 = 21 days, and I3= 28 days) It was found that three plants per hill produced highest total and marketable yields of roots (24.75 and 21.12 Mg/ha, respectively), while single plant per hill produced the lowest yields of roots (11.42 and 9.5 Mg/ha, respectively). It was observed that irrigation interval at 21 days interval had produced the highest total and marketable yields of roots (22.4 and 19.2 t/ha, respectively),

The objectives of the present investigation are to;

- Develop a seeder from local materials to be suitable for carrot-seed planting.
- Optimize by inspecting the different operating parameters.

MATERIALS AND METHODS

Materials:

The developed carrot-seeder:

The developed carrot-seeder was constructed at a local workshop and tested at a private farm in Sharkia Governorate . The developed carrot seeder as shown in fig. 1 consists of the main frame with three hitching points, seed box, 12 vertical roller with round cells metering-device, 12 plastic seed-tubes, 12 shovel furrow-openers and 12 chain covering device. The overall dimensions of the developed carrot-seeder are 155 cm in length, 95 cm in width and 85 cm in height and its mass is about 185 kg.

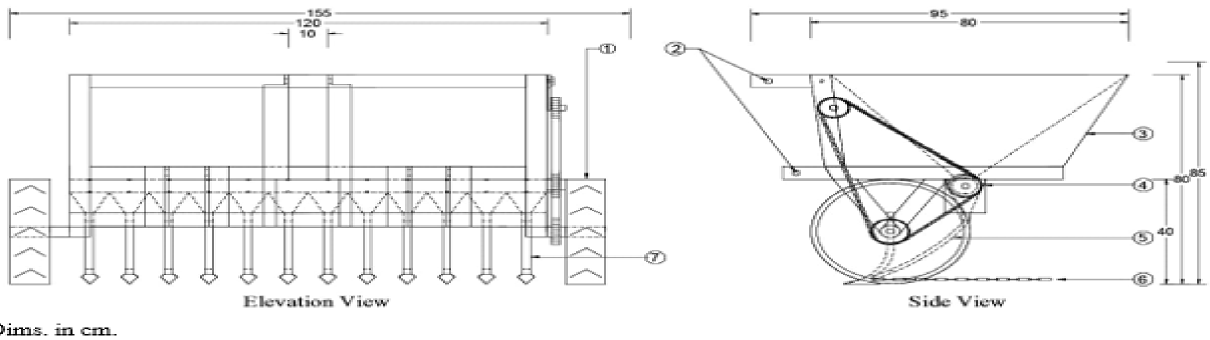

Fig. 1. Elevation and side view of the carrot seeder.

(1) Ground wheel, (2) Hitching points, (3) Seed hopper, (4) Metering device, (5) Seed tube, (6) Covering device and (7) Furrow opener.

The developed carrot-seeder consists of the following parts:

- **Frame:** The frame was built from iron angle with dimensions of 50 x 50 x 5 mm. The frame has length of 130 cm, width of 60 cm and height of 65 cm.
- **Seed box:** The seed box was built from sheet steel 3 mm thick, with dimensions of 120 x 50 x 25 cm and 58^o sloping bottom.
- **Metering device:** The metering device consists of vertical roller with 4 round cells cutoff and housing. The plastic vertical roller has a diameter of 7 cm and width of 4 cm. The round cell has 4 round cells with depth of 3.5 mm and tested diameters of 3.5, 7 and 10.5 mm (cell sizes are 1, 2 and 3 coated seed/cell). Fig. 2 shows isometric of metering device and cutoff.
- **Cuttoff:** The cutoff was made of rubber with 40 mm thickness and 60 mm width. The cutoff has a square gate with dimensions of 20 x 20 mm. The carrot seeds drop from seed hopper inside the gate of cutoff to metering-device cells.

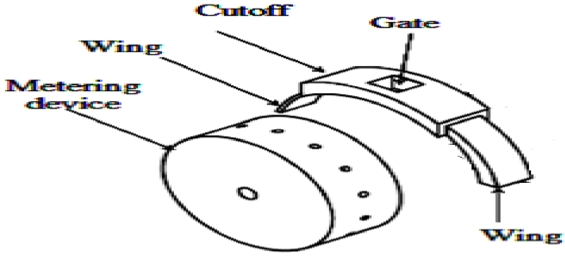

Fig. 2. Isometric of the metering device and cutoff.

- **Seed tube:** Plastic seed tube has diameter of 5 cm , length of 60 cm and thickness of 2 mm.
- **Furrow opener:** Shovel furrow-opener has share width of 6 cm.
- **Covering device:** Chain covering-device consists of 10 iron rings with diameter of 10 cm.

Tractor: A Kubota tractor (Model: L295) of 30 hp (22.4 kW) drew the developed carrot seeder.

Carrot seeds: Carrot-seeds variety "Atlas" was used in this study. Physical and mechanical properties of seeds was measured and calculated according to "Mohsinin, 1986". The uncoated and coated carrot-seed physical and mechanical properties are shown in table 1. The coated carrot-seeds were treated by "Arsan.50" fungicide, "Fe" and "Zn" with concentration of 5 g per kg carrot seeds according to Abd-Al Fattah *et al*. (2015).

Table 1. Physical and mechanical properties of carrot seeds.

Seed properties	Uncoated seed				Coated seed			
	Max..	Min.	Av.	SD	Max.	Min.	Av.	SD
L, mm.	1.63	1.58	1.61	0.54	3.22	3.12	3.16	0.23
W, mm.	0.84	0.73	0.80	0.36	3.36	3.27	2.32	0.21
T, mm.	0.62	0.52	0.58	0.09	2.12	2.04	2.08	0.23
M_{1000}, g.	2.22	2.18	2.21	0.01	9.44	9.32	9.36	0.09
$\square_R$, g/cm^3.	1.08	1.01	1.03	5.72	1.16	1.06	1.13	8.76
$\square_B$, g/cm^3.	0.53	0.44	0.48	6,12	0.83	0.74	0.77	3.42
Sphercity	0.61	0.59	0.6	0.17	0.78	0.76	0.77	0.06
Friction angle (steal surface), degree.	15.67	15.64	15.65	0.01	12.98	12.94	12.95	0.01

Min: minimum, Max.: maximum, Av.: average, SD: standard deviation, L: length, W: width, T: thickness, M_{1000}: mass of 1000 seeds, $\square_R$: real density and $\square_B$: bulk density.

Methods:

Two experimental groups were carried out to study the effect of some operating-factors on the developed carrot-seeder performance as follows:

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

(2) Field experiments: were carried out to determine the following indicators: longitudinal seed-distribution, slip of ground wheel, draft force, power, specific energy, field capacity, emergence percentage, crop yield, and estimating the costs of using the machine.

Planting intensity ranges were 0.44 - 2.01 and 2.01 - 7.71 kg/fed for uncoated and coated seeds respectively. The planting intensity was varied according to the number of seed per cell, forward speed and seed treatment (uncoated and coated seeds). The field experiment included four forward speeds of 2, 3, 4, and 5 km/h.

Tested parameters:

- **Metering-device speed:** Seven metering-device speeds of 20, 40, 60, 80, 100, 120 and 140 rpm (0.07, 0.15. 0.22, 0.29, 0.37, 0.44 and 0.51 m/s) corresponding to ground speeds of 10, 20, 30, 40, 50, 60 and 70 rpm (0.72, 1.44, 2.16, 2.88, 3.60, 4.32, and 5.04 km/h or 0.2, 0.4, 0.6 0.8, 1.0, 1.2 and 1.4 m/s) were tested in laboratory.
- **Cell size:** Three cell-sizes of 1, 2 and 3 seed/cell (cell depth of 3.5 mm and cell diameters of 3.5, 7 and 10.5 mm respectively) were tested in the laboratory and field.
- **Forward speed:** Four forward-speeds of 2, 3, 4 and 5 km/h (corresponding to the metering-device speeds of 56, 84, 112 and 140 rpm) were tested in laboratory and field.
- **Seed treatment:** Uncoated seeds with length range of 1.61 - 1.63 mm, width range of 0.73 - 0.84 mm and thickness range of 0.52 - 0.62 mm, and coated seeds with maximum length range of 3.12 - 3.22 mm, width range of 3.27 - 3.36 mm and thickness range of 2.04 - 2.12 mm were tested.

Measurements:

Seed discharge: Seed discharge was measured in laboratory and field tests at different ground-wheel speeds of 10, 20, 30, 40, 50, 60 and 70 rpm or metering-device speeds of 20, 40, 60, 80, 100, 120 and 140 rpm and cell sizes of 1, 2 and 3 seed/cell, forward speeds of 2, 3, 4 and 5 km/h for uncoated and coated seeds. Uncoated seeds were mixed with sand with a mass ratio of 1 seed : 3 sand.

The fed seeds were collected in plastic bags during a certain number (20) of ground-wheel revolutions.

Seed damage and germination: After each experiment, the damaged seeds were sorted manually and weighed. The percentage of seed-damage were calculated, and related to the seed discharge.

One thousand carrot seeds were germinated to give the real germination ratio before passing through the metering device.

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

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

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

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

Emergence percentage: The number of plantings per meter of the row was counted for the four tested- speeds of 2, 3, 4, and 5 km/h and cell-sizes of 1, 2 and 3 seed/cell for uncoated and coated seed to determine the emergence percentage according to the following formula:

$$\text{Emergence } percentage = \frac{\text{No. of germinated seeds}}{Total No. of seeds} \times 100$$

Longitudinal plant-distribution: For forward speeds, the carrot 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:

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

Where: **SD is the standard deviation.**

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

$$\text{Missing hills } (\%) = \frac{\text{Number of missing } plants \text{ per meter}}{Total\,n\,umber\,of\,plants \text{ per meter}} \times 100$$

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 equation (Awady, 1992).

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

Where: **theoretical dist. = No. of wheel revs. x □ x wheel diameter.**

Total and fruit yield: The total and fruit yield of each plot was measured to study the effect of the above-mentioned factors on carrot crop. A frame of 1 x 1 m^2 was used for measuring the yield. It was placed at random once every 20 plots. The yield of the crop located within the frame was measured. The average fruit and total yield was calculated for all treatments in Mg/fed (ton/fed).

Actual field capacity ($F.C_{act}$): The actual field capacity was calculated using the following equation:

$$F.C._{act} = \frac{1}{T_t} \quad \text{fed/h}$$

Where: **T = Actual time consumed for planting one feddan, h/fed.**

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

$$\eta_f = \frac{F.C._{act}}{F.C._{th}} \times 100$$

Where: **η_f = Filed efficiency, %,**

$F.C._{act.}$ = Effective field capacity, fed/h

$F.C._{th.}$ = Theoretical field capacity, fed./h.

Draft force and power: A hydraulic dynamometer was used to measure the pulling force. It was calibrated before and after experiments. Pulling force (F), Newton can be converted as follows:

$$\mathbf{F} = \frac{\pi}{4} \times (D_1^2\ D_2^2) \times P$$

Where: **D_1: diameter of piston, (0.04 m), D_2: diameter of connecting rod, (0.018 m) and P: dynamometer pressure, (N/m^2).**

Required power: Power was calculated by using the following formula:

Power, kW = Draft force, kN x forward speed, m/s

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

$$\text{Specific energy (kW.h/fed.)} = \frac{\text{Power required (kW)}}{\text{Actual field capacity (fed/h)}}$$

Total operating cost of using the developed carrot-seeder: The total hourly cost was calculated according to equation of (Awady, 1978) in the following form:

$$C = \frac{P}{h}\left(\frac{1}{a} + \frac{i}{2} + t + r\right) + (1.2\ w.s.f\ ) + \frac{m}{144}, \quad \text{L.E/h} \qquad (12)$$

Where:

C = Total hourly cost, L.E/h. **P = Price of machine, L.E.**
h = Yearly working hours, h/year. **a = Life expectancy of the machine, year.**
i = Interest rate/year. **f = Fuel price, L.E/l.**
t = Taxes, over heads ratio. **r = Repairs and maintenance ratio.**
m = Monthly average wage, L.E **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:

$$\text{Operational cost} = \frac{\text{Total cost (L.E/h)}}{\text{Effective field capacity (fed/h)}}, \quad \text{(L.E/fed)}$$

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 carrot-seeder. Laboratory experiments help to adjust the machine under the optimum conditions during the filed experiments.

Effect of metering-device speed and cell size on uncoated and coated carrot-seed discharge.

Figs. 3 and 4 show the effect of metering-device speed and cell size on uncoated and coated carrot-seed discharge and seeding rate. Results showed that seeding rate decreased by increasing metering-device speed and increased by increasing cell size.

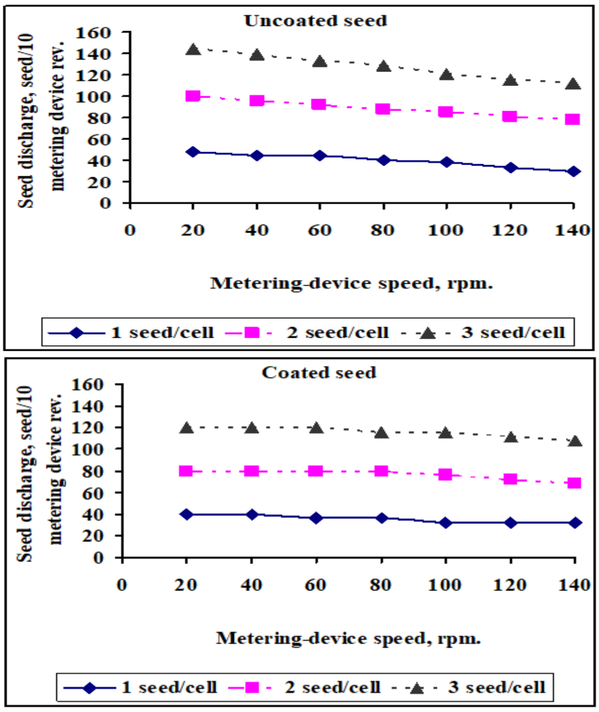

Fig. 3. Effect of metering-device speed and cell size on seed discharge of uncoated and coated carrot-seeds.

The maximum seed discharges or seeding rates of 144 and 120 seed/10 revolutions of metering device or 2.218 and 7.863 kg/fed (about 84000 and 70000 seed/fed) were obtained at metering speed of 20 rpm (ground-wheel speed of 10 rpm) and cell size of 3 seed/cell for uncoated and coated seeds, respectively. Meanwhile, the minimum seed discharges or seeding rates of 30 and 32 seed/10 revolutions of metering device or 0.462 and 2.097 kg/fed (17500 and 18670 seed/feed) were obtained at metering speed of 140 rpm (ground-wheel speed of 70 rpm) and cell size of 1 seed/cell for uncoated and coated seeds respectively.

Results show that by increasing metering-device speed from 20 to 70 rpm the seeding rates were decreased by about 25 and 13 % for uncoated and coated seeds respectively.

The decreasing of carrot discharge by increasing metering device speed is due to that the time is not enough to fill all cells of metering-device by seeds.

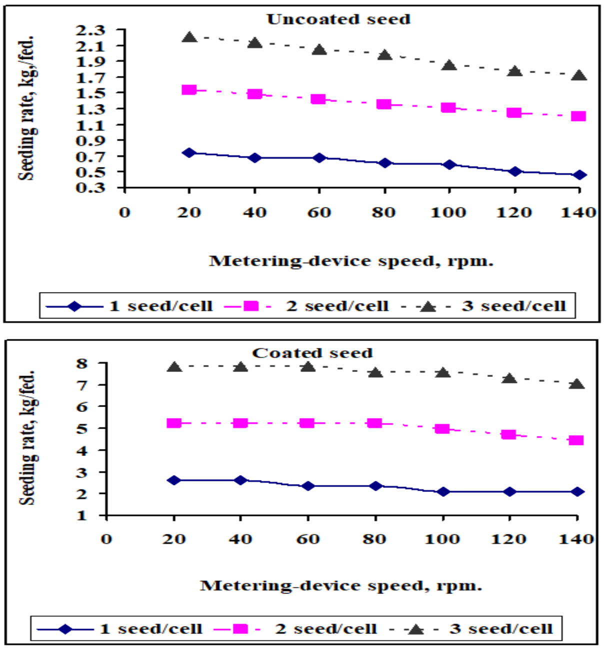

Fig. 4. Effect of metering-device speed and cell size on seeding rate of uncoated and coated carrot-seeds.

Effect of metering-device speed and cell size on uncoated and coated carrot-seed damage percent.

Fig. 5 shows the effect of metering-device speed and cell size on uncoated and coated-seed damage percent. Results showed that seed damage increased by increasing metering-device speed and decreased by increasing cell size.

The maximum carrot-seed damages of 0.90 and 0.81 % were obtained at metering-device speed of 70 rpm or ground speed of 140 rpm and cell size of 3 seed/cell using uncoated and coated seeds, respectively. Meanwhile, the minimum carrot-seed damages of 0.13 and 0.02 % were obtained at metering device speed of 20 rpm or ground-wheel speed of 10 rpm and cell size of 1 seed/cell for uncoated and coated seeds, respectively.

The increase in grain damage by increasing metering device speed is due to increasing momentum of grains (momentum = mass x velocity) and increasing impact force accordingly.

Effect of metering-device speed, cell size on uncoated and coated-seed germination percent.

Fig. 6 shows the effect of metering-device speed and cell size on uncoated and coated-seed germination percentage. The results showed that carrot-seed germination decreased by increasing metering-device speed and decreasing cell size.

The maximum carrot-seed germinations of 97.44 and 98.06 % were obtained at metering-device speed of 20 rpm or ground speed of 10 rpm and cell size of 3 seed/cell using uncoated and coated seeds, respectively. Meanwhile, the minimum carrot-seed germinations of 94.09 and 95.2 % were obtained at metering device speed of 140 rpm or ground-wheel speed of 70 rpm and cell size of 1 seed/cell for uncoated and coated seeds, respectively.

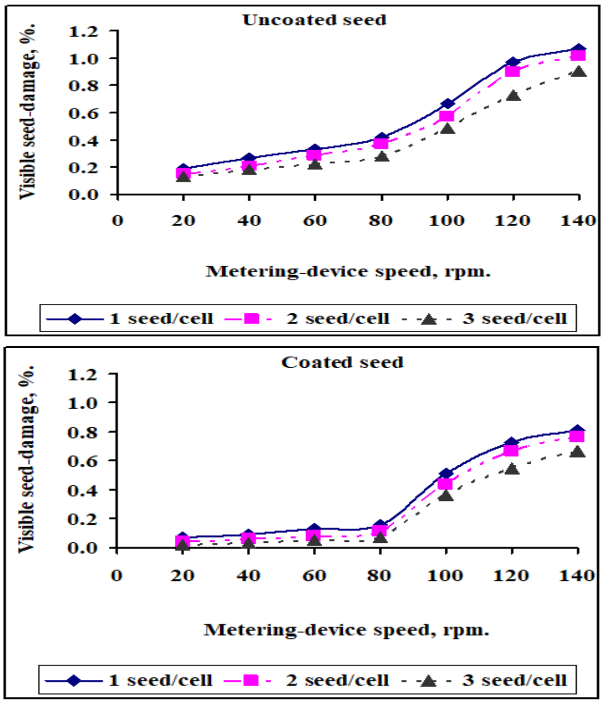

Fig. 5. Effect of metering-device speed and cell size on visible damage of carrot seeds.

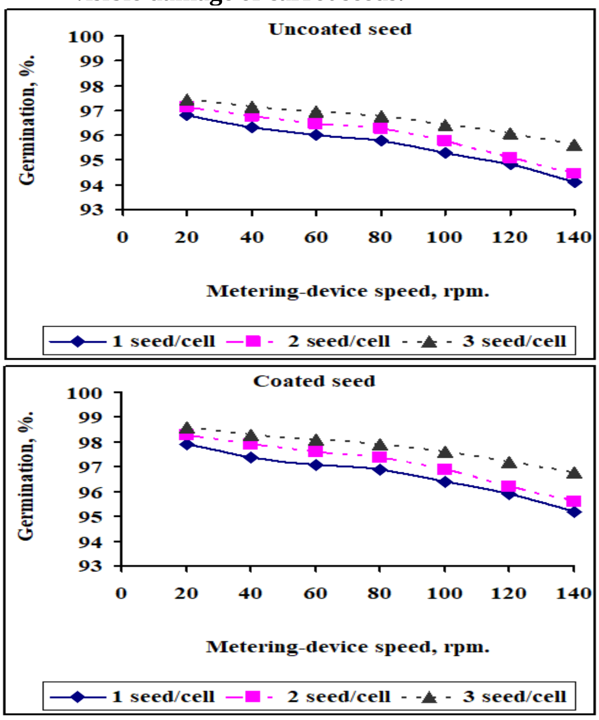

Fig. 6. Effect of metering-device speed and cell size on uncoated and coated carrot-seeds germination.

2. Results of field experiments:

Effect of forward speed and cell size on uncoated and coated carrot seeding-rate.

Fig. 7 shows the effect of forward speed and cell size on uncoated and coated carrot seeding-rate. Results showed that seeding rate decreased by increasing forward speed and decreasing cell size.

The maximum seeding rates of 2.01 and 7.71 kg/fed were obtained at metering speed of 20 rpm (ground-wheel speed of 10 rpm) and cell size of 3 seed/cell using uncoated and coated seeds respectively. Meanwhile, the minimum seeding rates of 0.44 and 2.01 kg/fed were obtained at metering-device speed of 70 rpm or ground speed of 140 rpm and cell size of 1 seed/cell using uncoated and coated seeds, respectively. The decreasing of seeding rate of field experiments compared with laboratory experiments is due to ground-wheel slip. But the trend of results is still the same.

Effect of forward speed and cell size on carrot-plant emergence percent using uncoated and coated seed.

Fig. 8 shows the effect of forward speed and cell size on carrot plant-emergence using uncoated and coated seeds. Results showed that plant emergence decreased by increasing forward speed and decreasing cell size.

The maximum carrot-plant emergences of 95.11 and 97.15 % were obtained at forward speed of 2 km/h and cell size of 3 seed/cell using uncoated and coated seeds respectively. Meanwhile, the minimum carrot-plant emergences of 92.01 and 94.22 % were obtained at forward speed of 5 km/h and cell size of 1 seed/cell for uncoated and coated seeds respectively.

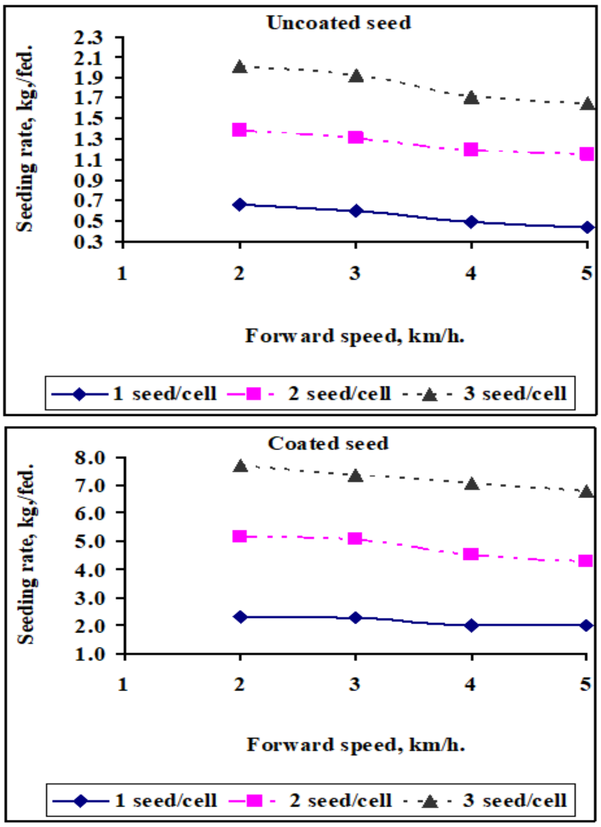

Fig. 7. Effect of forward speed and cell size on seeding rate of uncoated and coated carrot-seeds.

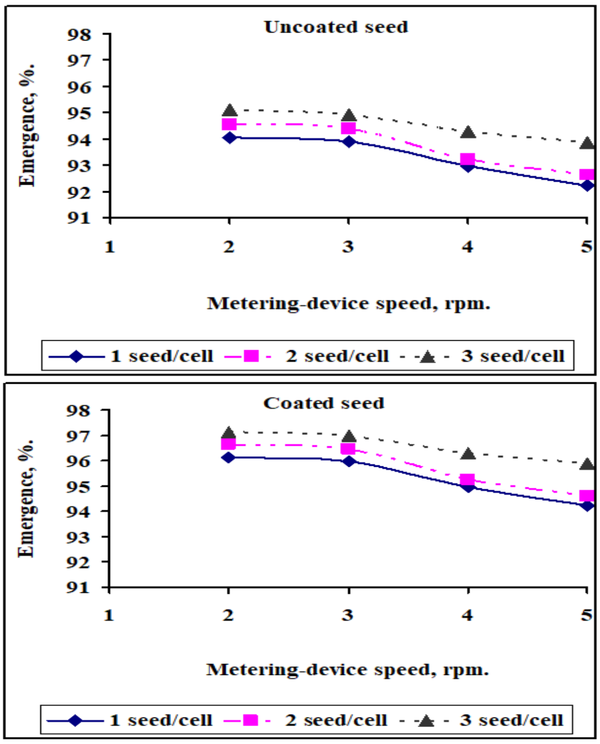

Fig. 8. Effect of forward speed and cell size on carrot-plant emergence for uncoated and coated seeds.

The increasing of emergence for coated seeds compared to uncoated seeds may be due to the coated carrot-seeds were treated by “Arsan.50” fungicide, “Fe” and “Zn”, increasing coated seed-size which more controlled and distribution and more protection against birds.

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.

Effect of forward speed and cell size on average number of uncoated and coated carrot seeds per hill.

Table 2 shows the effect of cell size and forward speed and cell size on maximum, minimum and average number of uncoated and coated carrot-seeds per hill.

The results show that the maximum number of carrot seeds per hill of 5 was obtained with cell size of 3 seed/cell and forward speed of 2 km/h using the mixture of uncoated seeds and sand. Meanwhile, the minimum numbers of carrot seeds per hill of 1 was obtained with cell size of 1 seed/cell and using coated seeds at any forward speeds.

The decreasing of number of carrot seed per hill by increasing forward speed is due to the time is not enough to fill the cells of metering device.

There no effect of forward speed on numbers of carrot seeds per hill because of the corresponding metering-device speeds gave accepted filling rate of cells by seeds.

Effect of forward speed on longitudinal hill-distribution.

Table 3 shows the effect of forward speed on average and C. V. of carrot hill-spacing.

Table 2. Effect of cell size and forward speed on maximum, minimum and average number of uncoated and coated carrot-seeds per hill.

Seed type	Cell size, grains/cell.	Forward speed, km/h.	Max. No. of grains/hill.	Min. No. of grains/hill.	Average No. of grains/hill.	C. V.
Uncoated seeds	1	2	4	2	3	4.3
		3	3	3	3	4.7
		4	2	2	2	5.2
		5	2	2	2	5.6
	2	2	5	2	4	4.6
		3	5	2	4	4.9
		4	4	2	3	5.4
		5	4	2	3	5.6
	3	2	6	3	5	4.4
		3	6	3	5	5.2
		4	5	3	4	5.3
		5	5	3	4	5.7
Coated seeds	1	2	2	1	1	4.3
		3	2	1	1	4.7
		4	1	1	1	5.2
		5	1	1	1	5.6
	2	2	3	2	2	4.6
		3	3	2	2	4.9
		4	2	2	2	5.4
		5	2	2	2	5.6
	3	2	4	3	3	4.4
		3	4	3	3	5.2
		4	3	3	3	5.3
		5	3	3	3	5.7

Table 3. Effect of forward speed and cell size on maximum, minimum and average hill-spacing for uncoated and coated carrot-seeds.

Seed type	Cell size, grains/cell.	Forward speed, km/h.	Max. hill spacing, cm.	Min. hill spacing, cm.	Av. hill spacing, cm.	C. V.
Uncoated seeds	1	2	12	10	11	5.4
		3	13	10	11.5	5.6
		4	15	12	13.5	7.8
		5	16	13	14.5	11.1
	2	2	11	10	10.5	4.2
		3	12	11	11	5.1
		4	12	11	11.5	5.8
		5	13	12	12	7.9
	3	2	11	10	10	3.9
		3	12	10	10.5	4.6
		4	12	10	10.5	4.8
		5	13	11	11	5.1
Coated seeds	1	2	12	10	11	4.1
		3	12.5	10	11.1	4.6
		4	13	11	11.8	5.4
		5	13.5	12	12.2	5.8
	2	2	11	10	10.5	3.2
		3	11	10	10.5	3.7
		4	12	10	11.5	3.9
		5	12	10	11.5	4.3
	3	2	11	10	10.5	2.9
		3	11	10	10.5	3.1
		4	12	10	11	3.4
		5	12	10	11	3.9

The plants distribution was analyzed in order to determine the frequency, average and coefficient of variation (CV) of wheat hill-spacing. A low CV represents a row with more uniform hill spacing.

The optimum conditions clarify that the forward speed of 2 km/h had the best longitudinal seed distribution: average carrot hill-spacing of 11, 10.5 and 10 cm with CV of 5.4, 4.2 and 4.1 % using uncoated seeds and 11, 10.5 and 10.5 cm with cv of 4.1, 3.2 and 2.9 for cell sizes of 1, 2 and 3 seed/cell respectively. Using the large cell size gave more accurate hill spacing and less coefficient of variation.

The increasing of hill spacing by increasing forward speed is due to increasing ground-wheel slip in addition to the increase of machine vibration. Meanwhile, the decreasing of hill spacing by increasing of cell size is due to decreasing the missing hills.

Effect of forward speed on missing-hills percent.

Fig. 9 shows the effect of forward speed on missing-hill percent of carrot plants using uncoated and coated seeds. In general, decreasing the speed and increasing the cell size gives less missing hills.

The minimum missing-hills percent of 3.7 and 1.7 % were obtained with forward speed of 2 km/h and cell size of 3 seed/cell using uncoated and coated seeds respectively. Meanwhile, the maximum missing-hills percent of 8.9 and 6.6 % was obtained with forward speed of 5 km/h and cell size of 1 seed/cell using uncoated and coated seeds respectively.

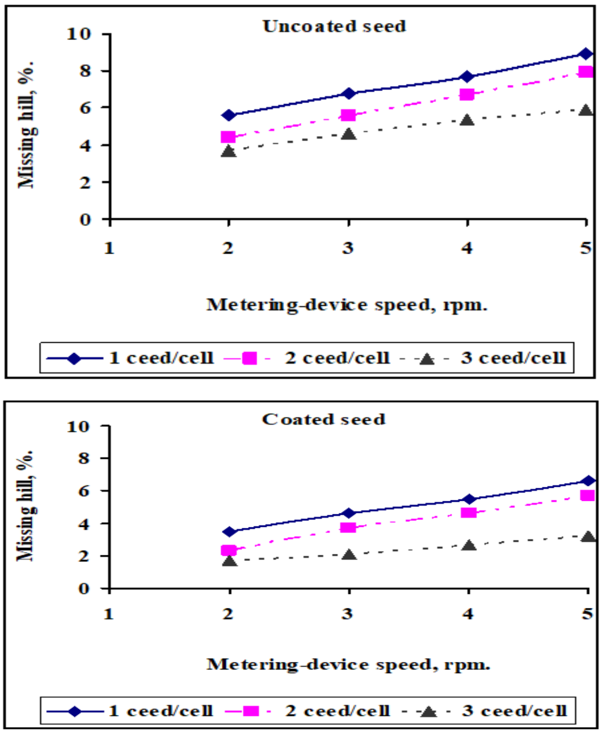

Fig. 9. Effect of forward speed on missing-hills percent of carrot plants using uncoated and coated seeds.

Effect of forward speed and cell size on carrot-fruit yield using uncoated and coated seeds.

Fig. 10 shows the effect of forward speed and cell size on carrot-fruit yield using uncoated and coated seeds. Carrot-fruit yield decreased by increasing forward speed and decreasing cell size.

The maximum carrot-fruit yields of 13.11 and 18.62 Mg/fed were obtained at forward speed of 2 km/h and cell size of 3 seed/cell for uncoated and coated seeds respectively.

Meanwhile, the minimum carrot-fruit yields of 7.03 and 9.83 Mg/fed were obtained at forward speed of 5 km/h and cell size of 1 seed/cell for uncoated and coated seeds respectively.

The decrease in wheat-grain yield by increasing forward speed is due to the low plant emergence resulting from ground wheel slip at high speed. Also due to grain damage occurred by the effect of the metering device.

Factors affecting carrot-fruit yield were combined into multiple regression-equation as follows:

$$Y = 10.19 - 3.55\ S + 1.70\ N_s \qquad (R^2 = 0.95)$$

Uncoated seed

$$Y = 12.87 - 4.075\ S + 2.53\ N_s \qquad (R^2 = 0.97)$$

Coated seed

Where: Y: Carrot-fruit yield, Mg/fed, S: Forward speed, m/s and No. of seeds/cell.

Effect of forward speed on ground-wheel slip.

Fig. 11 shows the effect of forward speed on wheel slip percent. The slip percent of ground wheel increased with increasing forward speed. The maximum slip of 5.13 % was obtained with forward speed of 5 km/h. Meanwhile the minimum slip of 3.13 % was obtained with forward speed of 2 km/h.

Increasing the slip is due to the vibration of grain-drill wheels caused by increasing forward speed.

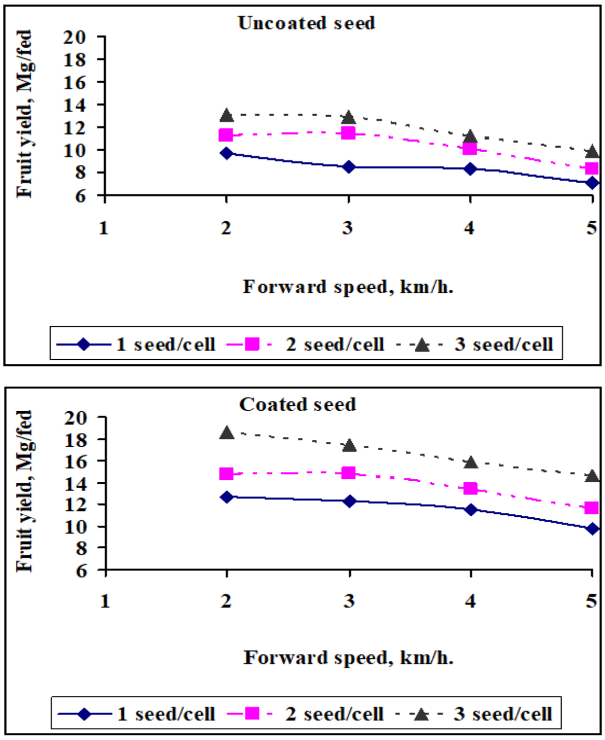

Fig. 10. Effect of forward speed and cell size on fruit yield using uncoated and coated seeds.

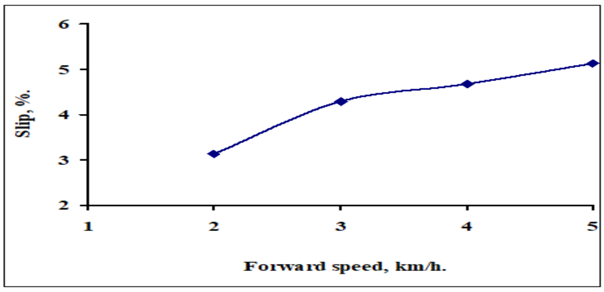

Fig. 11. Effect of forward speed on ground-wheel slip percent.

Effect of forward speed on effective field-capacity and field efficiency.

Fig. 12 shows the effect of forward speed on effective field-capacity and field efficiency. The maximum field capacity of 1.14 fed/h and minimum field-efficiency of 79.8 % was obtained with forward speed of 5 km/h. Meanwhile the minimum field-capacity of 0.51 fed/h and maximum field-efficiency of 89.88 % was obtained with forward speed of 2 km/h.

Effect of forward speed on draft force, required power and specific energy.

Figs. 13 and 14 show the effect of forward speed on draft force, required power and specific energy. The maximum draft force, required power and specific energy of 5.22 kN, 7.25 kW and 6.36 kW.h/fed were obtained with forward speed of 5 km/h. Meanwhile, the minimum draft force, required power and specific energy of 4.44 kN, 2.47 kW and 4.80 kW.h/fed were obtained with forward speed of 2 km/h.

Operational costs of using the developed carrot-seeder.

Table 4 shows operation and production costs of using the developed seeder at different forward-speeds and cell-sizes for uncoated and coated carrot-seeds.

The operational cost decreased by increasing forward speed. The minimum hourly and operational (according to prices of year of 2021) of 64.97 L.E./h and 56.99 L.E./fed were obtained using the developed carrot seeder with forward speed of 5 km/h, cell size of 3 seed/cell and coated seeds. Meanwhile, The maximum hourly and operational costs of 141.74 L.E./h, and 275.97 L.E./fed were obtained using the developed carrot seeder with forward speed of 2 km/h, cell size of 1 seed/cell and coated seeds. The cost of manual carrot-seed planting was 600 L.E./fed.

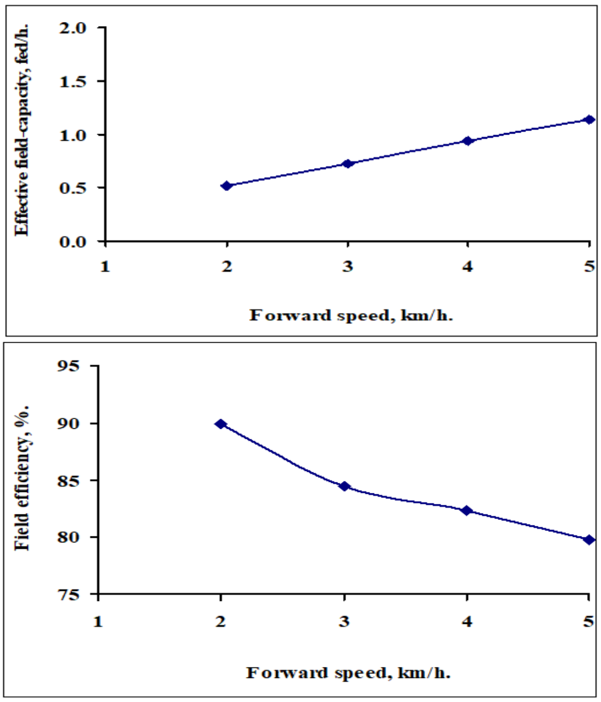

Fig. 12. Effect of forward speed on effective field-capacity and field efficiency.

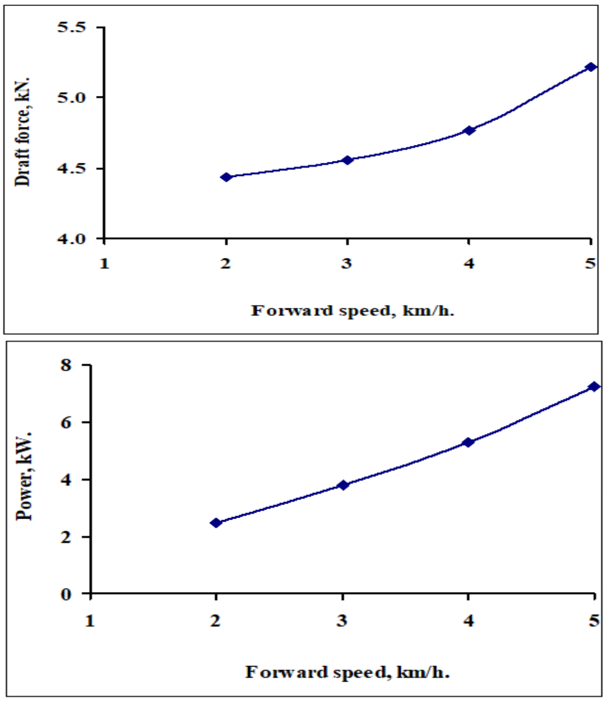

Fig. 13. Effect of forward speed on draft force and power,

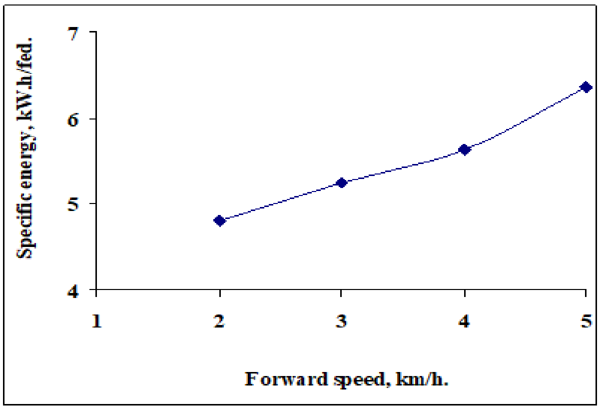

Fig. 14. Effect of forward speed on specific energy,

Table 4. Operational and production costs of using the developed seeder at different forward-speeds and cell-sizes for uncoated and coated carrot-seeds.

Seed type.	Forward speed, km/h.	Hourly cost, L. E./.h.	Operational cost, L. E./.fed.
Uncoated	2	141.74	275.97
	3	88.58	122.39
	4	76.77	81.59
	5	64.97	56.99
Coated	2	141.74	275.97
	3	88.58	122.39
	4	76.77	81.59
	5	64.97	56.99

CONCLUSION

The obtained results from this investigation recommend the use of the developed carrot seeder under the following optimum-conditions: cell size of 3 seed/cell, forward speed of 5 km/h and coated seeds. The obtained results with optimum conditions were: plant emergence of 95.9 %, average hill-spacing of 11 cm, average grain/hill of 3, ground-wheel slip of 5.13 %, draft force of 5.22 kN, power of 7.25 kW, specific energy of 6.36 kW.h/fed, field capacity of 1.14 fed/h, Hourly and operational cost of 64.97 L/E./h and 56.99 L.E/fed, and production cost of 3.90 L.E./Mg.

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تطوير وتقييم آلة لزراعة بذور الجزر

إبراهيم يحيى ، فاطمة الزهراء على عبد الجواد ،عادل أحمد الجيزاوى و جمال عبدالحميد الترمذى
معهد بحوث الهندسة الزراعية – مركز البحوث الزراعية – الدقي – الجيزة – مصر.

الهدف من هذا البحث هو تطوير وتقييم آلة لبذر الجزر. وتم تصميم وتصنيع جهاز تلقيم عبارة عن بكرة رأسية ذات أربع خلايا. وتم أجراء مجموعتين من التجارب: أولاً: التجارب المعملية: تم دراسة سبعة سرعات لجهاز التلقيم وهى 20، 40، 60، 80، 100، 120، 140لفة/د وسرعات عجلة الأرض هى 10، 20، 30، 40، 50، 60، 70لفة/د على التوالى وثلاث أحجام لخلايا جهاز التلقيم وهى: 1، 2، 3 بذرة/خلية، لبذور غير مغلفة وبذور مغلفة بمبيد فطرى أرسان، حيد، زنك. ثانياً: التجارب الحقلية: تم أختبار أربع سرعات أمامية وهى 2، 3، 4، 5 كم/س مع نفس أحجام خلايا جهاز التلقيم السابقة للبذور غير المغلفة والبذور المغلفة. وكانت أهم النتائج كالتالى: * فى الاختبارات المعملية، وجد أن أقصى معدل زراعة لبذور الجزر وهو 2.218، 7.863 كج/فدان تم الحصول عليه مع سرعة عجلة الأرض 10 لفة/دقيقة (سرعة جهاز التلقيم 20 لفة/دقيقة) وحجم بذرة 3 بذور/خلية باستخدام البذور غير المغلفة والمغلفة على التوالى. بينما تم الحصول على أقل معدل زراعة وهو0.462، 2.097 كج/فدان مع سرعة عجلة الأرض 70 لفة/دقيقة (سرعة جهاز تلقيم 140 لفة/دفيقة) وحجم خلية 1 بذرة/خلية باستخدام البذور غير المغلفة والمغلفة على التوالى. * فى الإختبارات المعملية، وجد أن أعلى نسبة تلف لحبوب الجزر وهو 0.90، 0.81 % تم الحصول عليها مع سرعة عجلة الأرض 70 لفة/دقيقة (سرعة جهاز تلقيم 140 لفة/دفيقة) وحجم خلية 1 بذرة/خلية باستخدام البذور غير المغلفة والمغلفة على التوالى. بينما تم الحصول على أقل نسبة تلف لحبوب الجزر 0.13، 0.02 % مع سرعة عجلة الأرض 10 لفة/دقيقة (سرعة جهاز التلقيم 20 لفة/دقيقة) وحجم خلية 3 بذرة/خلية باستخدام البذور غير المغلفة والمغلفة على التوالى. * وجد أن أقصى نسبة بزوغ لبادرات الجزر وهو 95.11 ، 97.15 % تم الحصول عليها مع سرعة أمامية 2 كم/ساعة وحجم خلية 3 بذرة/خلية باستخدام البذور غير المغلفة والمغلفة على التوالى. بينما تم الحصول على أقل نسبة بزوغ لبادرات الجزر 92.01، 94.22 % مع سرعة أمامية 5 كم/ساعة وحجم خلية 1 بذرة/خلية باستخدام البذور غير المغلفة والمغلفة على التوالى. * أعطت السرعة أمامية 2 كم/ساعة وحجم خلية 1 بذرة/خلية أفضل أنتظامية توزيع للجور، حيث كان متوسط المسافة بين الجور 10، 10.5 سم بمعامل أختلاف 4.1، 2.9 % باستخدام البذور غير المغلفة والمغلفة على التوالى. * وجد أن أقل نسبة جور مفقودة 3.7، 1.7 % تم الحصول عليها مع سرعة أمامية 2 كم/ساعة وحجم خلية 3 بذرة/خلية باستخدام البذور غير المغلفة والمغلفة على التوالى. بينما تم الحصول على أقصى نسبة جور مفقودة 8.9، 6.6 % مع سرعة أمامية 5 كم/ساعة وحجم خلية 1 بذرة/خلية باستخدام البذور غير المغلفة والمغلفة على التوالى. *وجد أن أقصى إنتاجية ثمار جزر 13.11، 18.62ميجاجرام/فدان تم الحصول عليها مع سرعة أمامية 2 كم/ساعة وحجم خلية 3 بذور/خلية باستخدام البذور غير المغلفة والمغلفة على التوالى. بينما تم الحصول على أقل إنتاجية ثمار جزر 27.03، 9.83 ميجاجرام/فدان مع سرعة أمامية 5 كم/ساعة وحجم خلية 1 بذرة/خلية باستخدام البذور غير المغلفة والمغلفة على التوالى. * وجد أن أقل تكاليف تشغيل 56.99 جنية / فدان تم الحصول عليها بإستخدام جهاز آلة زراعة بذور الجزر المطورة مع سرعة أمامية 2 كم /ساعة وحجم خلية 3 بذرة/خلية والبذور المغلفة. ووجد أيضاً أن تكاليف التشغيل للزراعة اليدوية فى جور 600 جنيه/فدان.