A NEW SEED DRILL FOR PLANTING PEAS ON A RAISED-BED

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سطارة جديدة لزراعة البسلة على مصاطب

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ABSTRACT

Until now, the traditional method for planting pea seeds is manual because of the scarcity of planting machines. Therefore, this study aims to provide and evaluate a new seed drill for planting pea seeds on a raised bed in silt-clay loam soil. This seed drill consists of the frame, seeds hopper, seed metering device, transmission system, and covering unit. Laboratory tests on pea seeds were conducted to determine the seeds' physical and mechanical properties. Field trials were carried out under the following parameters; four forward speeds (0.79, 0.98, 1.28, and 1.64 m s^{-1}), three disc cell capacities (1, 2, and 3 seeds per cell), two different cells shapes (circular, and a rectangle with semicircle end), and three distances between rows (7.5, 10, and 15 cm) to assess the performance of the seed drill on fuel consumption, specific energy, slip ratio, seeds damaged, germination ratio, plants number per hill, longitudinal scattering, and pea pods yield. The results revealed that the optimum performance of the seed drill was achieved at a forward speed ranging from 0.79 to 0.98 m s^{-1}, using a disc cell capacity of 2 seeds, a circular cell shape, and a distance between rows of 10 cm.

الملخص

لا تزال حتى الآن زراعة بذور البازلاء في مصر بالطريقة التقليدية (يدويا) بسبب قلة الآلات المخصصة للزراعة. لذلك ، تهدف هذه الدراسة إلى توفير وتقييم سطارة جديدة لزراعة بذور البازلاء على مصاطب في تربة طينية. حيث تتكون السطارة من الاطار وقادوس البذور وجهاز تلقيم البذور ونظام النقل ووحدة التغطية. أجريت الاختبارات المعملية على بذور البازلاء لتحديد الخصائص الفيزيائية والميكانيكية للبذور. أجريت التجارب الحقلية وفقًا للمعايير التالية ؛ أربع سرعات أمامية (0.79 ، 0.98 ، 1.28 ، 1.64 م ث -1) ، ثلاث سعات لخلية القرص (1 ، 2 ، 3 بذور لكل خلية) ، شكلين مختلفين للخلايا (دائري ، ومستطيل بنصف دائرة فى نهايته) ، وثلاث مسافات زراعة بين الصفوف (7.5 ، 10 ، 15 سم) لتقييم أداء السطارة على استهلاك الوقود ، والطاقة النوعية ، ونسبة الانزلاق ، والبذور التالفة ، ونسبة الإنبات ، وعدد النباتات في كل جورة، والتشتت الطولي ، وانتاجية البازلاء. أوضحت النتائج أن الأداء الأمثل للسطارة تم تحقيقه بسرعة أمامية تتراوح من 0.79 إلى 0.98 م ث -1 ، باستخدام سعة خلية القرص بذرتين لكل خلية، وشكل الخلية الدائري ، ومسافة الزراعة بين الصفوف 10 سم.

INTRODUCTION

Pea (*Pisum sativum* L.) is one of the extremely crucial legume species (*Krizmanić et al., 2020*); it is a fundamental source of high-quality proteins, micronutrients, starch, phenolic compounds, dietary fibers, and antioxidants (*Yu et al., 2021*). Pea seeds are smooth or wrinkled; the weight of 100 seeds ranges from 10 to 36 g. Pea plants up to 80 per square meter at 3 to 5 cm depth, about 10 cm apart in rows (*Garden peas production, 2011*). The peas' seeds are sown directly in the soil by 10 kg of seeds at an area of 1000 square meters at a depth of 2 to 3 cm, with a plant spacing of 7 to 10 cm (*Burt, 2008*). Furthermore, sown pea seeds in hills with a space of 15 cm apart in rows using two seeds per hill and thinned the hill to one plant 15 days after germination. In addition, adjusted input seeds accurately in the rows at control depth and spacing, and the seeds were covered with soil and provided proper compaction of the seed (*Zaki et al., 2017*).

The manual planting method of seeds has numerous disadvantages; for example, it causes low seed placement, spacing efficiencies, severe backache for the farmer, and decreases the crop field's active area (*Kyada and Patel, 2014*). Moreover, *Vimal et al. (2015)* manufactured a multi-purpose sowing machine suitable for various seeds and small farms with lower operating costs. The influence of planting speed on the seed accuracy of metering devices was studied. Their results found that higher planting speeds led to more hills without seeds, an inaccurate distance between hills, and increased average spacing (*Khan et al., 2017*). A seeder for planting grains on ridges and flat lands was developed. The results reported that the distance between plants, uniformity of seed distribution, and the ratio of seed emergence are the most common characteristics to assess the performance of the seeder (*Olaoye and Bolufawi, 2001*).

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Afify, (2009), developed a seed drill feeding device suitable for planting medical and aromatic seeds in hills between rows of 40 cm, four operating speeds, and four distances between hills. The results revealed that the optimal distance between hills was 30 cm to obtain a high yield of seeds of 340 kg ha^{-1} and low specific energy of 7.24 kWh tonne^{-1}. Furthermore, a high germination ratio of 95.37% and a high field efficiency of 89.41% at a forward speed of 3.13 km h^{-1}. A manual multi-crop seeder was developed and evaluated, and the results indicated the seeder had field capacity and field efficiency of 0.39 ha h^{-1} and 76.3%, respectively. Also, the percentage difference between the seed damage was 1.32%, 2.32%, and 3.54% for soybean, maize, and cowpea, respectively, at the average distance between hills of 40.8 cm and a depth of 3.98 cm (*Adekanye and Akande, 2015*).

Moreover, a prototype planter was manufactured for planting wheat seeds on a wide-width row. The results recommended that the optimum seed planting performance was achieved at an operating speed of 4.36 km h^{-1}, a metering cell capacity of 8 seeds. The operation under the previous parameters recorded low energy consumption of 1.26 kWh ha^{-1}, a high grain yield of 1.22 tonnes ha^{-1}, and a high germination ratio of 97.78% (*Awad, 2016*).

Finally, because of the lack of machines that plant pea seeds on terraces in Egypt, the current study aims to provide and evaluate the performance of a new seed drill for planting pea seeds on a raised bed and determine the optimum operating conditions for the seed drill under this study.

MATERIALS AND METHODS

The description of the seed drill

Figure 1 shows the seed drill's photography view, elevation, and side views. All seed drill parts were manufactured and modified at a local workshop in El-Zahaira Village, El-Snbellaween City, Dakahlia Governorate, Egypt. The seed drills' overall dimensions are 150 × 120 × 100 cm (length, width, and height). The total weight of the seed drill is 1.96 kN. The seed drill consists of a frame with L-shaped iron section with dimensions of 140 × 40 × 5 cm (L × W × H), with a thickness of 6 mm. Three-point hitch made of iron plates with a thickness of 2 cm and a width of 10 cm; it was manufactured according to (*ASABE standard, 2003*). The hitch pin is 2.5 cm in diameter, the upper-hitch point is at the height of 60 cm from the lower-hitch point, and the lower-hitch point is at the height of 65 cm from the ground. The seeds hopper is made of an iron sheet with a thickness of 2 mm. It has a trapezoid shape and a slope angle of 70° on two sides, which is more than the repose angle of pea seeds (25.0°–28.7°), according to (*Khan et al., 2017*). The maximum capacity of the seeds hopper is 50 kg. Figure 2 presents the seed metering device, which consists of seven feeding discs made of Teflon with a thickness of 5 cm; on the periphery of the feeding disc, the seed cells were formed in two different shapes and dimensions. The diameter of the feeding disc was about 16 cm. The feeding disc diameter was calculated according to Eq. (1) as follows:

$$Dm = \frac{Dw}{Gr} \tag{1}$$

where Dm is the diameter of the feeding disc [cm], Dw is the ground wheel diameter of the seed drill [cm], and Gr is the gear ratio.

The number of cells on the circumference of the feeding disc was calculated according to (*Khan et al., 2017*), as follows in Eq. (2).

$$Number\ of\ cells\ = \frac{\pi\ \times\ Diameter\ of\ seeder\ ground\ wheel\ (cm)}{Gear\ ratio\ \times\ Intra\ row\ spacing\ of\ seeds\ (cm)} \tag{2}$$

According to equation (2), the number of cells is (6 cells/disc). The cell of seeds was manufactured at three disc cell capacities (one "C1 cell volumetric capacity of 0.42 cm^3", two "C2 cell volumetric capacity of 0.63 cm^3", and three "C3 cell volumetric capacity of 1.26 cm^3" seeds per cell) and two different cell shapes (circular "S1" and a rectangle with semicircle end "S2", as shown in Fig. (2). Each disc was fixed inside the iron case as a cylinder shape with internal and external diameters of 16.1 and 17.0 cm, respectively. The top of the iron case has a hole with a diameter of 21 mm to enter the seeds from the hopper to the disc cells, but on the other side, the bottom has a hole to flow the seeds into the seed tube and consequently to the seedbed. All the feeding discs were installed on an iron shaft with a length of 150 cm and 30 mm in diameter. Each end of the feeding shaft was mounted in a standard cast iron pillow block bearing UCP206, and the shaft took its movement from the ground wheel. The transmission unit consists of two gears. The first gear is fixed on the seed drill's wheel shaft and has 45 teeth with a diameter of 20 cm. The second gear is fixed on the feeding shaft and has 14 teeth with a diameter of 6 cm. The motion transmits at different diameters from 48.0 cm to 16.0 cm of the ground wheel at a ratio speed of discs shaft of 1:3, this ratio adding accurately the numbers of hills related to the peripheral speed of the ground wheel. A control bar made of iron with a length of 120 cm and a width of 2 cm has holes in equal distances of 2.5 cm and was used to control and adjust the rows' distances. Seven shares with dimensions of 6.0 × 2.5 cm (L × W) are attached in the control bars' holes to cut the soil with the desired depth of 3.0 cm to ease the pea seeds' sown in the recommended depth. At the top of each share is a pipe with a diameter of 2.5 cm and a length of 4.0 cm to install the seeds' tubes. Seven seed tubes made of PVC with a length of 35 cm and a diameter of 2.54 cm are attached between the seed metering device and the shares to ensure the correct positioning of the seed in the allotted place. A chain with a length of 2 m was used as a covering unit to cover the hills with soil after executing the seeding operation. The seed drill is mounted at the rear of a 32 kW tractor (Daedong D4351, 4WD with a fuel tank capacity of 43.5 liters) as a power source to execute all field experiments in this study.

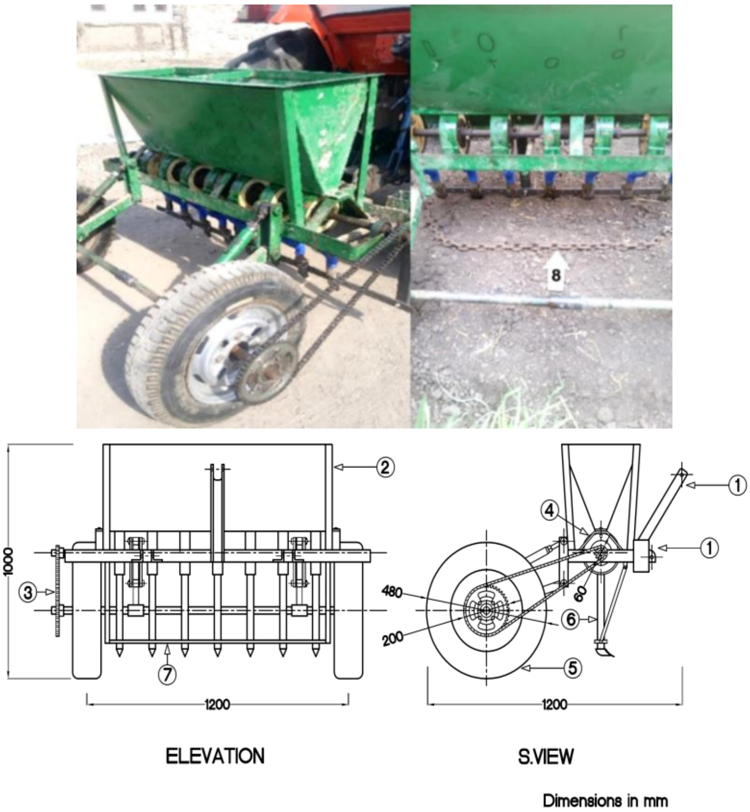

Fig. 1 – Photo, elevation and side views of the seed drill

1 – Three-point hitch; 2 – Seeds hopper; 3 – Chain drive transmission system; 4 – Seed metering device; 5 – Ground wheel; 6 – Seed tube; 7 – The control bar of the planting depth and distance between rows; 8 – Covering unit (chain)

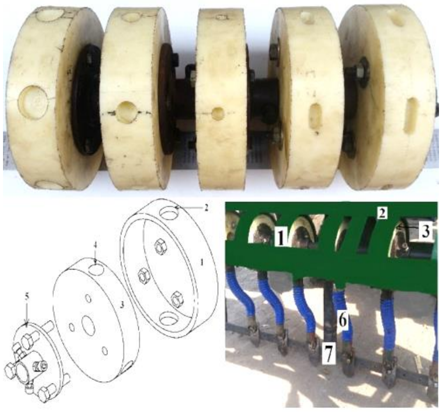

Fig. 2 – The seed metering device

1 – The disc's case; 2 – The seed input hole; 3 – The cell's disc; 4 – The cell of seeds; 5 – The assembly unit; 6 – The seeds' tubes; 7 – The shares

Field trials

The field trials were carried out during the winter season of 2021 in an area of about 1.6 ha after the maize crop. The trials were arranged at four forward speeds of 0.79, 0.98, 1.28, and 1.64 m s^{-1}, three disc cell capacities of one "C1", two "C2", and three "C3" seeds per cell, two cells shapes of circular "S1", and a rectangle with semicircle end "S2", and three distances between rows of 7.5 "D1", 10 "D2", and 15 cm "D3".

The trial area was divided into 216 plots; each plot had a length of 50 m and a width of 1.2 m to assess the seed drill's performance under the studied variables. The field experiments were executed at an average soil moisture content of 14% (dry basis) and an average seeding depth of 3 cm. All treatments were replicated three times in a randomized complete block design. The trials were executed on Master B variety of pea at a farm in El-Zahaira Village (31°28'21.23" E, longitude; 30°55'7.66" N, latitude; and 11 m altitude), Dakahlia Governorate, Egypt. The seed drill sows seven rows with different distances of 7.5, 10, and 15 cm between rows on a terrace that top width is 90 cm, the terrace's total width is 120 cm, and 8.4 cm between the hills in the row, as shown in Fig. (3). The mechanical analysis of the experimental soil was carried out at the Soil, Water, and Environment Research Institute (SWERI), Agricultural Research Center (ARC), Egypt. The experimental soil's texture is silt-clay loam with clay, silt, fine sand, and coarse sand percentages of 35.15, 42.60, 18.42, and 3.83%, respectively.

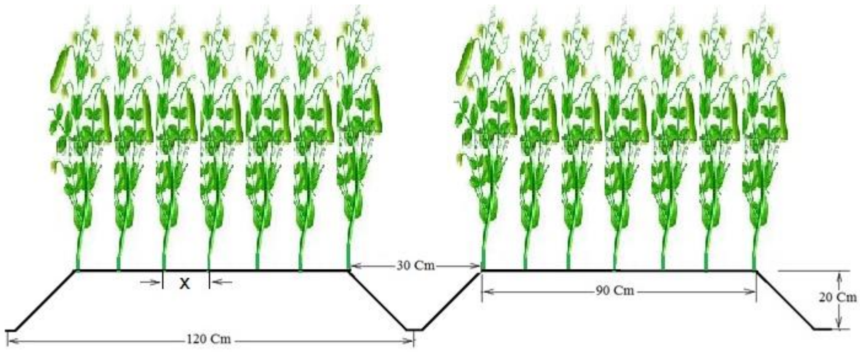

Fig. 3 – Sketch of the terraces' dimensions

Measurements

Measurements on pea seeds before sowing

Laboratory tests were conducted on pea seeds before the sowing operation to determine some physical and mechanical properties of Master B variety pea seeds. An electronic digital caliper with an accuracy of 0.01 mm was used to measure the seeds' dimensions. A graduated cylinder with a volume of 500 cm^3 was used to measure the volume of the investigated seeds to obtain true and bulk density. An electronic digital balance with an accuracy of 0.01 g was used to determine the mass of the seeds' samples to calculate bulk density. A digital coefficient of friction device with an accuracy of 0.01 degrees was used to measure the coefficient of friction of pea seeds on a metal sheet surface. The pea seed's repose angle was measured using an angle of repose tester to measure the angle between the base and slope of cone-formed seed mass. In order to estimate seed damage and germination ratio, five kilograms of pea seeds were sorted manually, and the percentage of damaged seeds was calculated. After that, the remaining pea seeds were put into the hopper, and the ground wheel was rotated to receive the seeds into a packet at the end of the seed tube. Then, the seeds were sorted, and the percentage of damaged seeds was calculated.

Furthermore, five hundred pea seeds were germinated to calculate the actual germination ratio before passing the pea seeds through the seed metering device. The actual germination ratio of seeds was calculated according to (*Yehia, 1993*), as follows in Eqs. (3–5).

All treatments were replicated five times, and the average of the obtained results is presented in Table (1).

$$\begin{aligned}&Actual\ germination\ percent = \\ &Germination\ percent\ of\ unsound\ seeds - (visible\ seed\ damage\ [\%] + \\ &invisible\ seed\ damage, [\%])\end{aligned} \tag{3}$$

$$Visible\ seed\ damage\ (\%) = \frac{Weight\ of\ damaged\ seeds\ (g) \times 100}{Total\ weight\ of\ seeds\ (g)} \tag{4}$$

$$Invisible\ seed\ damage\ (\%) = \frac{No.\ of\ shoots\ \times\ 100}{Total\ No.\ of\ seeds} \tag{5}$$

.Table 1

Some physical properties of pea seeds

Characters / Variety	Static friction coefficient (SFC)	Mass of 100 seeds [g]	Bulk density [g cm^{-3}]	The average diameter of the seeds [mm]	Angle of repose	Moisture content [%, d.b.]
Master B	0.38	18.62	1.10	6.7	28.9°	9.26

Measurements on the seed drill

The measurements were performed on the seed drill, such as actual field capacity (ha h^{-1}), fuel consumption (l h^{-1}), specific energy (kWh ha^{-1}), and wheel slip ratio. The theoretical field capacity (TFC) was determined as follows in Eq. (6)

$$TFC = \frac{W \times S \times 1000}{10000} \tag{6}$$

where TFC is the theoretical field capacity [ha h^{-1}], W is the seed drill's width [m], and S is the seed drill's forward speed [km h^{-1}]

The actual field capacity (AFC) was determined according to (*Srivastava et al., 1993*), as follows in Eq. (7).

$$AFC = \frac{1}{T} \tag{7}$$

where AFC is the actual field capacity [ha h^{-1}], T is the total actual operation time per hectare [h ha^{-1}] (T = Tm + Tt + Tp), Tm is maintenance and lubrication time [h ha^{-1}], Tt is turning time [h ha^{-1}], and Tp is parasitic time [h ha^{-1}]

The fuel consumption rate was measured according to (*Elsbaay and Hegazy, 2016*), as follows in Eq. (8).

$$FCR = \frac{FCV}{1000} \times \frac{60}{OT} \tag{8}$$

where FCR is the fuel consumption rate [l h^{-1}], FCV is the fuel consumption volume [ml], and OT is the operating time [min]

The specific energy (SE) was calculate according to (*Hunt, 1983*), as follows in Eq. (9).

$$SE\ (kWh\ ha^{-1}) = \left(\frac{FCR \times \rho f \times LCV}{3600}\right) \times \left(\frac{427 \times \eta th \times \eta mec}{75 \times 1.36 \times AFC}\right) \tag{9}$$

where SE is specific energy [kWh ha^{-1}], FCR is fuel consumption rate [l h^{-1}], ρf is fuel density [0.85 kg l^{-1} for diesel], LCV is lower calorific value of fuel [10000 kcal kg^{-1}], 427 is thermo-mechanical equivalent [J $kcal^{-1}$], ηth is engine thermal efficiency [≈ 35% for diesel engines], ηmec is engine mechanical efficiency [≈ 80% for diesel engines], and AFC is actual field capacity [ha h^{-1}].

The slippage ratio indicates the power loss due to the load. The slippage was determined according to (*ASABE standard, 2003*), as follows in Eq. (10).

$$S\ (\%) = \left(1 - \frac{Va}{Vo}\right) \times 100 \tag{10}$$

where S is the slippage [%], V_a is the actual speed of the loaded tractor in the field [km h^{-1}], and V_o is the tractor's speed without load on the concrete surface [km h^{-1}]

The seed drill sliding was determined as follows in Eq. (11).

$$S_m\ (\%) = \left(\frac{d1 - d2}{d2}\right) \times 100 \tag{11}$$

where S_m is the seed drill sliding [%], d1 is the actual distance for 10 revolutions of the seed drill wheels [m], and d2 is the theoretical distance for the same revolutions number of seed drill wheels [m]

Measurements on the crop growth

The crop yield is a function of some crop characteristics. Some characteristics are directly measured after sowing before irrigation operation, and the others are after germination and harvesting of the crop. The characteristics measurements include the number of seeds in the hills, seeds damaged, seed germination, longitudinal scattering, and crop yield.

Seeds' numbers in the hill were estimated after the sowing operation, and the number of seeds in each hill was determined manually by counting seeds in each hill at random.

In order to determine the percentage of seeds damaged, the seeds hopper was filled with pea seeds, and at the end of each seed tube, a plastic packet was fixed. The seed drill was operated in the field under different working speeds; all the seeds from each plastic packet were collected, the seeds damaged were counted and weighted, and the percentage of the seeds damaged was calculated, as follows in Eq. (12).

$$Percentage\ of\ seed\ damaged\ (\%) = \frac{W1}{W2} \times 100 \tag{12}$$

where W_1 is the weight of the seeds damaged [g], and W_2 is the total weight of the outlet seeds [g].

The seed germination ratio was calculated according to (*Safdary et al., 2020*), as follows in Eq. (13).

$$Seed\ germination\ ratio\ (\%) = \frac{N1}{N2} \times 100 \quad (13)$$

where N_1 is the number of seeds germinated in hills, and N_2 is the total number of seeds in hills.

The longitudinal scattering was measured in the intra-row spacing between 20 hills after two weeks from seeding pea seeds to determine the longitudinal scattering of seed placements statistically by standard deviation according to (*Steel and Torrie, 1980*), as follows in Eqs. (14–15).

$$sd = \sqrt{\frac{\Sigma(x - x^{-})^2}{n - 1}} \quad (14)$$

$$CV\ (\%) = \frac{sd}{x^{-}} \times 100 \quad (15)$$

where sd is the standard deviation, x is the distance between hills in a row [cm], x^{-} is the average distance [cm], n is the number of readings, and CV is the coefficient of variation in a row from an average distance [%]. Coefficients of variation under 10% are regarded as excellent; furthermore, values under 20% are regarded as generally acceptable for most field applications, according to (*Coates, 1992*).

The pea pod yield (kg ha^{-1}) was estimated by collecting the pea pods from five random areas for each treatment with an area of 1.0 m × 1.2 m, and the average of the pea pod yield was estimated and recorded.

RESULTS AND DISCUSSION

Effect of forward speed on fuel consumption

Figure 4 shows the influence of forward speed on fuel consumption during the seeding operation. The obtained results revealed that increasing forward speed significantly increased fuel consumption rates. Increasing the forward speeds from 0.79–0.98 m s^{-1}, 0.98–1.28 m s^{-1}, and 1.28–1.64 m s^{-1} increased fuel consumption rates from 3.75–3.96 l h^{-1}, 3.96–4.13 l h^{-1}, and 4.13–4.25 l h^{-1}, respectively. Furthermore, the lowest fuel consumption rate of 3.75 l h^{-1} was recorded at the lowest forward speed of 0.79 m s^{-1}. In contrast, the highest fuel consumption rate of 4.25 l h^{-1} was recorded at the highest forward speed of 1.64 m s^{-1}.

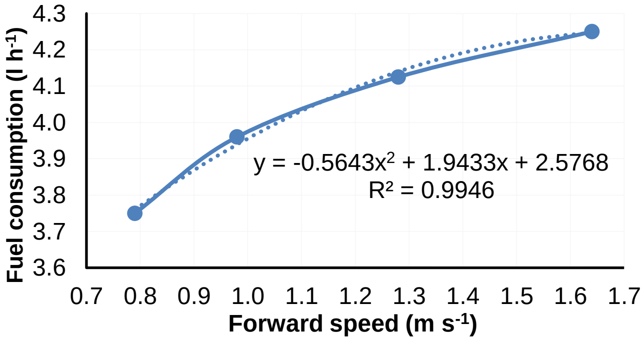

Fig. 4 – Effect of forward speed on fuel consumption

Effect of forward speed on specific energy

Figure 5 shows the influence of forward speed on specific energy. The results revealed that increasing the forward speed decreased specific energy. Increasing forward speed from 0.79–0.98 m s^{-1}, 0.98–1.28 m s^{-1}, and 1.28–1.64 m s^{-1} decreased specific energy by percent of 13.91%, 20.20%, and 18.40%, respectively. This may be attributed to the increased field capacity for high forward speeds. Whereas the highest specific energy of 7.25 kWh ha^{-1} was recorded at a forward speed of 0.79 m s^{-1}. On the other side, the lowest specific energy of 4.06 kWh ha^{-1} was recorded at a forward speed of 1.64 m s^{-1}.

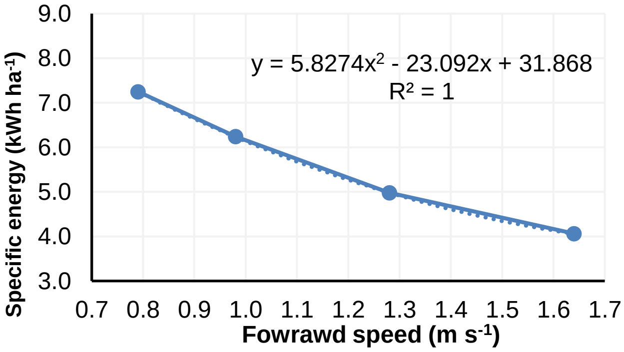

Fig. 5 – Effect of forward speed on specific energy

Effect of forward speed on slip ratio of the tractor and the seed drill

Figure 6 presents the slip ratio of the tractor and the seed drill wheels under the studied forward speeds. The data show that increasing the forward speed gave reasonable rates of increase in slip ratio. Increasing the forward speeds from 0.79–0.98 m s^{-1}, 0.98–1.28 m s^{-1}, and 1.28–1.64 m s^{-1} increased the tractor's slip ratio percentages by 6.50, 5.35, and 4.71%, respectively. On the other side, the seed drill's slip ratio increased by percent of 5.26, 7.32, and 4.65%, respectively, at the same forward speeds. This increment may be attributed to the increase in draft force. The slip ratio should be less than 15% for the seed drill with the tractor. Accordingly, the best operating forward speed is ranged from 0.79 to 1.64 m s^{-1} for executing the seeding operation:

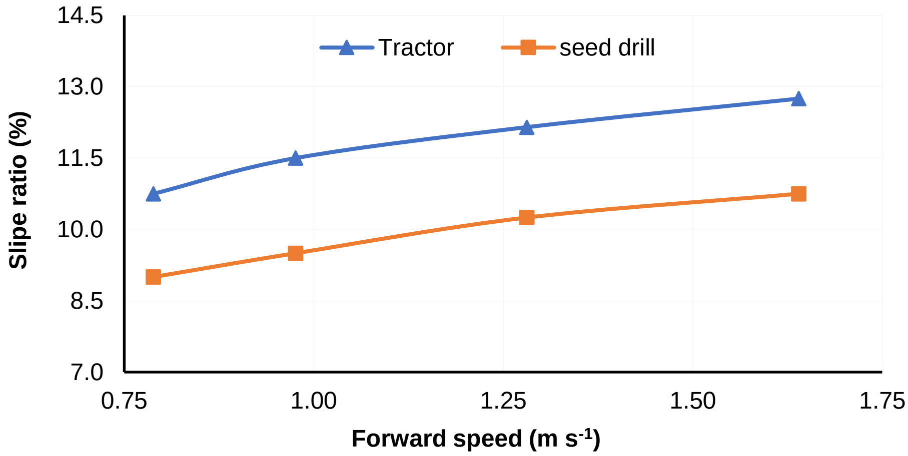

Fig. 6 – Effect of forward speed on slip ratio

Factors affecting crop growth and production

Effect of forward speed, cell shape, and disc cell capacity on the number of seeds per hill

Table (2) shows the influence of forward speed, cell shape, and disc cell capacity on the number of seeds per hill. The results revealed that at forward speeds of 0.79 and 0.98 m s^{-1}, the actual number of seeds per hill equals the number of cell capacities, and at the same time, increasing the forward speed from 0.98 to 1.64 m s^{-1}, the number of seeds decreased by 16.5%. This may be attributed to the increased forward speed, which in turn reduced the time required to fill the cells with the required number of seeds. Nevertheless, the maximum average number of seeds per hill with a disc cell capacity of 3 seeds was recorded at operating forward speeds ranging from 0.79 to 0.98 m s^{-1}. In contrast, the minimum average number of seeds per cell results from a disc cell capacity of 1 seed with an operating forward speed of 1.64 m s^{-1}.

On the other hand, regarding the effect of the different cell shapes, the results indicated that the number of seeds per hill was not affected by the different cell shapes.

Table 2

The average number of seeds per hill

Forward speed [m s^{-1}]	C_1		C_2		C_3	
	S_1	S_2	S_1	S_2	S_1	S_2
0.79	1.00	1.00	2.00	2.00	3.00	3.00
0.98	1.00	1.00	2.00	2.00	3.00	3.00
1.28	1.00	1.00	1.67	1.67	2.67	2.67
1.64	0.67	0.67	1.67	2.00	2.67	2.33

Effect of forward speed, cell shape, and disc cell capacity on seeds damage percentage

Figure 7 shows the influence of operating forward speed, cell shape, and disc cell capacity on seed damage percentage. Concerning the effect of the forward speed on seed damage percentage, increasing the forward speed from 0.79–0.98 m s^{-1}, 0.98–1.28 m s^{-1}, and 1.28–1.64 m s^{-1}, increased seed damage percentage from 2.08–2.28%, 2.28–2.45%, and 2.45–2.58%, respectively at using disc cell capacity of three seeds (C3) and circular cell shape (S1). At the same time, the corresponding values using a rectangle with a semicircle end cell shape (S2) increased from 2.40–2.53%, 2.53–2.67%, and 2.67–2.75%, respectively.

Regarding the effect of cell shape on seed damage percentage, the results revealed that using a circular cell shape (S1) increased seed damage percentages compared with using a rectangle with a semicircle end cell shape (S2). Whereas using a rectangle with a semicircle end cell shape (S2) at the disc cell capacity of three seeds (C3) increased seed damage percentage by percent of 13.33, 9.88, 8.24, and 6.18% at operating forward speeds of 0.79, 0.98, 1.28, and 1.64 m s^{-1}, respectively.

Concerning the effect of disc cell capacity on seed damage percentage, the results indicated that increasing disc cell capacity from one (C1) to three (C3) seeds increased the seed damage percentage. Increasing disc cell capacity from C1–C3 using circular cell shape (S1) increased seed damage percentage by percent of 30.29, 31.58, 32.24, and 31.00% at operating forward speeds of 0.79, 0.98, 1.28, and 1.64 m s^{-1}, respectively. The corresponding percentages using a rectangle with a semicircle end cell shape (S2) were 35.00, 34.00, 33.71, and 31.64% at operating forward speeds of 0.79, 0.98, 1.28, and 1.64 m s^{-1}, respectively.

The maximum seed damaged percentage of 2.75% was obtained at the forward speed of 1.28 m s^{-1}, the disc cell capacity of three seeds (C3), and the cell's shape as a rectangle with a semicircle end (S2). In contrast, the minimum seed damaged percentage of 1.45% was obtained at the forward speed of 0.79 m s^{-1}, the disc cell capacity of one seed (C1), and the cell's shape as circular (S1).

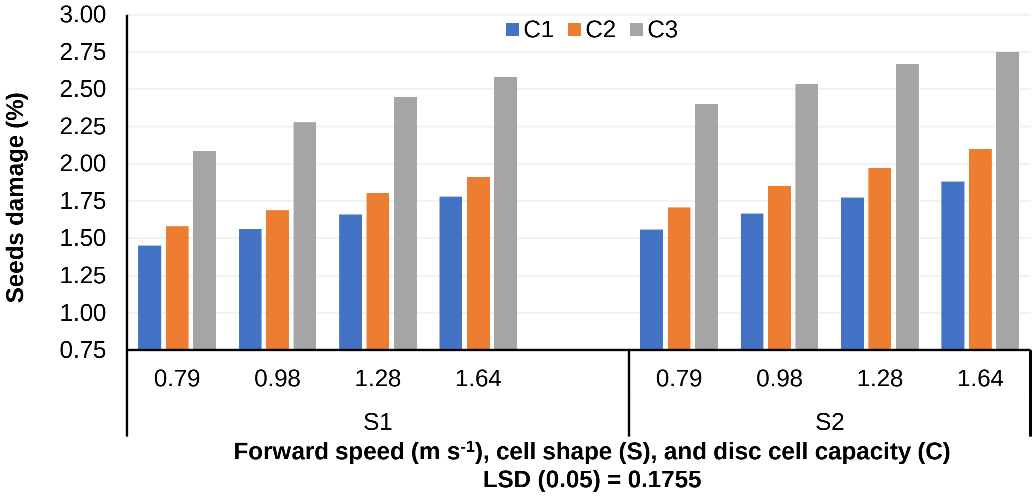

Fig. 7 – Effect of forward speed, cell shapes, and disc cell capacity on seeds damage percentage

Effect of forward speed, cell shape, disc cell capacity, and distance between rows on germination ratio of pea seeds

Laboratory germination percentage is not affected by passing pea seeds through the seed metering unit. Figure 8 presents the data concerning the germination ratio in the field. The data revealed that increasing forward speed decreased the germination ratio percentages. Increasing forward speed from 0.79–0.98 m s^{-1}, 0.98–1.28 m s^{-1}, and 1.28–1.64 m s^{-1} decreased germination ratios by percent of 1.00, 2.00, and 1.00%, respectively, using a circular cell shape (S1), disc cell capacity of three seeds (C3), and distance between rows of 7.5 cm (D1). On the other hand, the traditional method for pea seeds germination ratio recorded 88.90%. The highest germination ratio percentages were recorded at the forward speed of 0.79 m s^{-1} compared to the other forward speeds.

Regarding the effect of cell shape on the germination ratio of pea seeds, the results showed insignificant differences when using a circular shape (S1) or a rectangular with a semicircle end (S2) at different distances between rows.

Concerning the influence of disc cell capacity on the germination ratio percentage, the results indicated that increasing disc cell capacity from one to three seeds (C1–C3) increased the germination ratio at different forward speeds and cell shapes. Whereas increasing disc cell capacity from one to three seeds (C1–C3) increased germination ratios percent by 2.56, 2.55, 2.55, and 2.55%, at forward speeds of 0.79, 0.98, 1.28, and 1.64 m s^{-1}, respectively, at a circular cell shape (S1), and distance between rows of 7.5 cm (D1). At the same time, the corresponding percents at a rectangular with a semicircle end were 1.18, 2.55, 2.56, and 2.55%, respectively. The highest germination ratios percentages were achieved using the disc cell capacity of three seeds (C3).

Involving the effect of distance between rows on the germination ratio percentage, Figure 8 reveals that the germination ratio percentages were 93.44, 96.23, and 95.28% at distances between rows of 7.5, 10, and

15 cm, respectively, at a forward speed of 0.79 m s⁻¹, a circular cell shape (S1), and disc cell capacity of three seeds (C3). The results revealed that the maximum germination ratios percentages were recorded at a distance between rows of 10 cm compared with distances between rows of 7.5 and 15 cm.

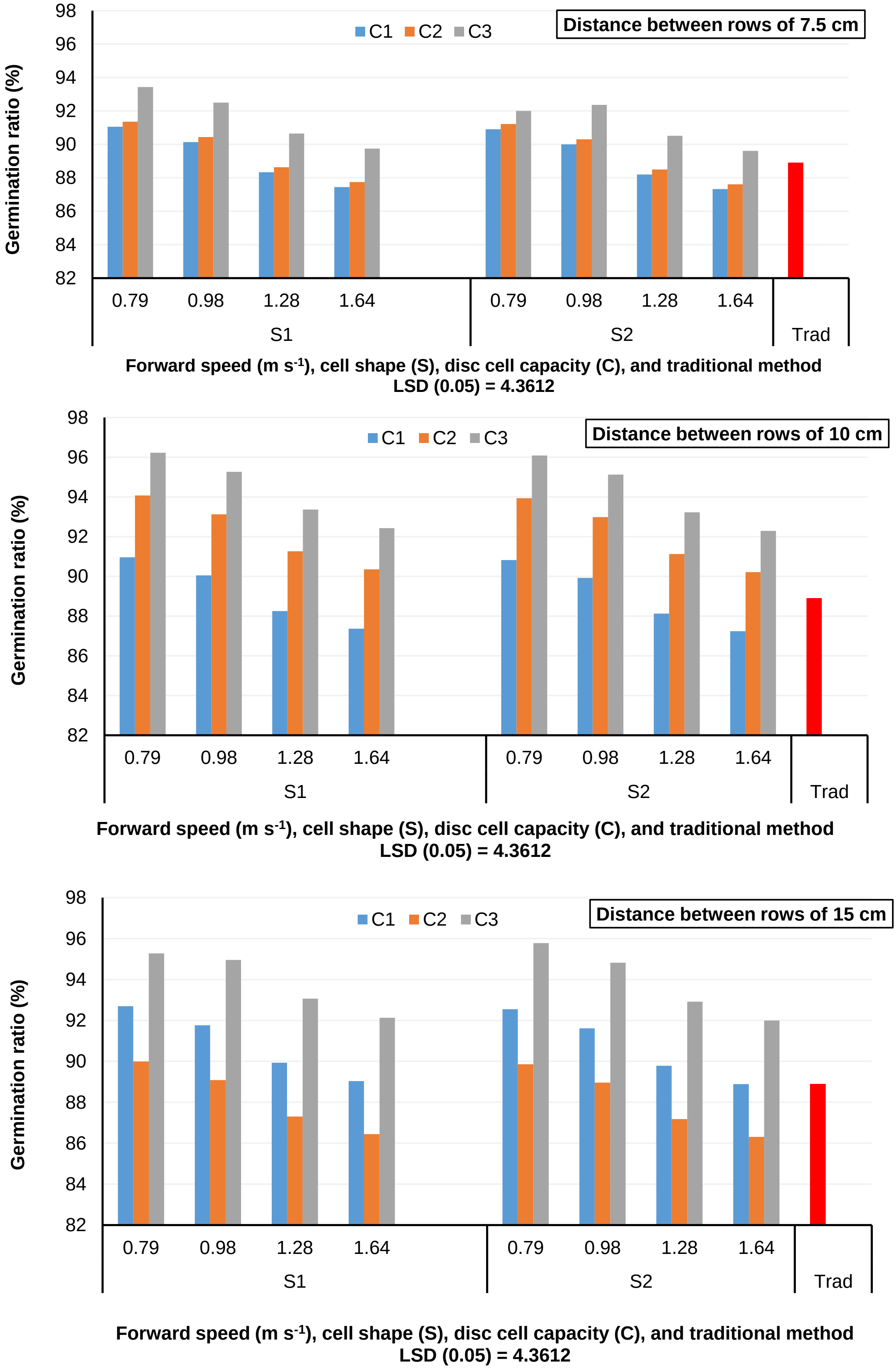

Fig. 8 – Effect of forward speed, cell shape, and disc cell capacity on germination ratio

Effect of forward speed, cell shape, and disc cell capacity on longitudinal scattering

Figure 9 illustrates the influence of forward speed, cell shape, and disc cell capacity on longitudinal scattering. Increasing forward speed increased longitudinal scattering at any cell shape and disc cell capacity. It can be observed that increasing the forward speed from 0.79–0.89 m s^{-1}, 0.89–1.28 m s^{-1}, and 1.28–1.64 m s^{-1} increased the longitudinal scattering from 12.5–14.0%, 14.0–15.6%, and 15.6–17.0%, respectively, at using disc cell capacity of one seed (C1), and a circular cell shape (S1). This may be due to more slips occurring at high operating forward speeds; moreover, high forward speeds generate more vibrations during seeding operating, which increases the seeding uniformity variation coefficient. These results are in harmony with *Liu et al. (2017)*, who stated that the coefficient of variation of seed spacing increased with increasing forward speed. In the same trend, *Sun et al. (2020)* reported that the seeding uniformity variation coefficient increases when the operating forward speed is higher or lower than 0.8 m s $^{-1}$.

Concerning the effect of the cell shape on longitudinal scattering, the results indicated that using a rectangular with a semicircle end (S2) compared with a circular cell shape (S1) increased longitudinal scattering values at any forward speed and cell shape. Using a rectangular with a semicircle end (S2) compared with a circular cell shape (S1) increased longitudinal scattering from 18.0–19.9%, 19.5–21.0%, 20.9–22.0%, and 22.0–22.5%, respectively, when using disc cell capacity of three seeds (C3).

Regarding the influence of disc cell capacity on longitudinal scattering, the results revealed that increasing disc cell capacity from one to three seeds per cell (C1–C3) led to increasing longitudinal scattering at any forward speed and cell shape. Increasing disc cell capacity from one to three seeds (C1–C3) increased longitudinal scattering from 12.5–18.0%, 14.0–19.5%, 15.6–20.95, and 17.0–22.0% for forward speeds of 0.79, 0.98, 1.28, and 1.64 m s^{-1}, respectively in case of using a circular cell shape (S1). Furthermore, the corresponding values in the case of using rectangular with a semicircle end (S2) increased from 13.0–19.9%, 14.0–21.0%, 15.0–22.0%, and 15.5–22.5%.

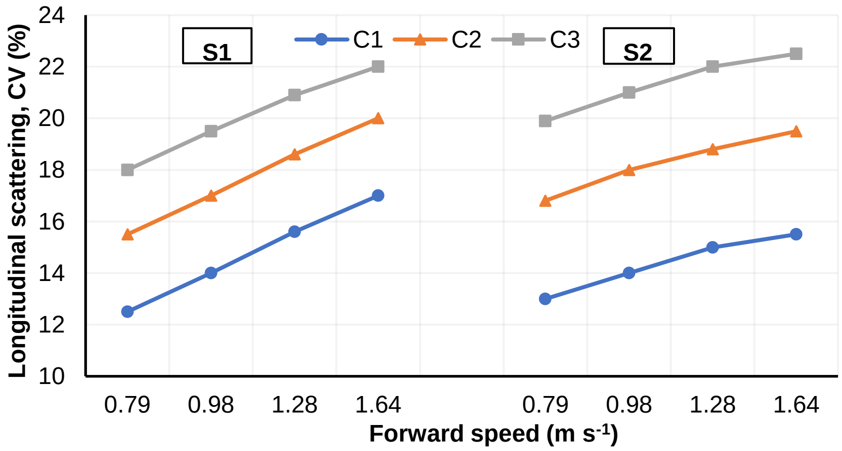

Fig. 9 – Effect of forward speed, cell shape, and disc cell capacity on longitudinal scattering

Effect of forward speed, cell shape, disc cell capacity, and distance between rows on the pea pods yield

Figure 10 shows the effect of forward speed, cell shape, disc cell capacity, and distance between rows on pea pods yield. The results revealed that increasing forward speed decreased the pea pod's yield at any cell shape, disc cell capacity, and distances between rows. Increasing the forward speed from 0.79–1.64 m s^{-1} decreased pea pods yield by a percent of 3.9% because the number of seeds damaged in the hill decreased the plant's growth.

Concerning the influence of cell shape on pea pods yield, the results indicated that using a semicircle end cell shape (S2) compared with a circular cell shape (S1) decreased the yield by a percent of 5.12% because of the increase in the number of seeds damaged. Concerning the effect of disc cell capacity on pea pods yield, the disc cell capacity of 2 seeds (C2) recorded the highest yield value compared with the disc cell capacity of one and three seeds (C1 and C3) at any forward speed, cell shape, and distance between rows.

Regarding the influence of the distance between rows on pea pods yield, the results indicated that distance between rows of 10 cm (D2) recorded the highest yield compared with distances between rows of 7.5 and 15 cm because of suitable seed numbers and distances between rows decreased the competition between the plants, which in turn leads to obtain the highest values of pea pods yield.

Consequently, the highest yield value of 1.22 tonnes ha^{-1} was recorded at a forward speed of 0.79 m s^{-1} and using a cell capacity of 2 seeds (C2).

In contrast, the traditional planting method recorded an average pea pods yield of 0.94 tonnes ha^{-1}. Finally, using the seed drill at a forward speed ranging from 0.79 to 0.98 m s^{-1} with the disc cell capacity of two seeds (C2) and the shape of a circular cell (S1) at a distance of 10 cm between rows (D2) is recommended under this study.

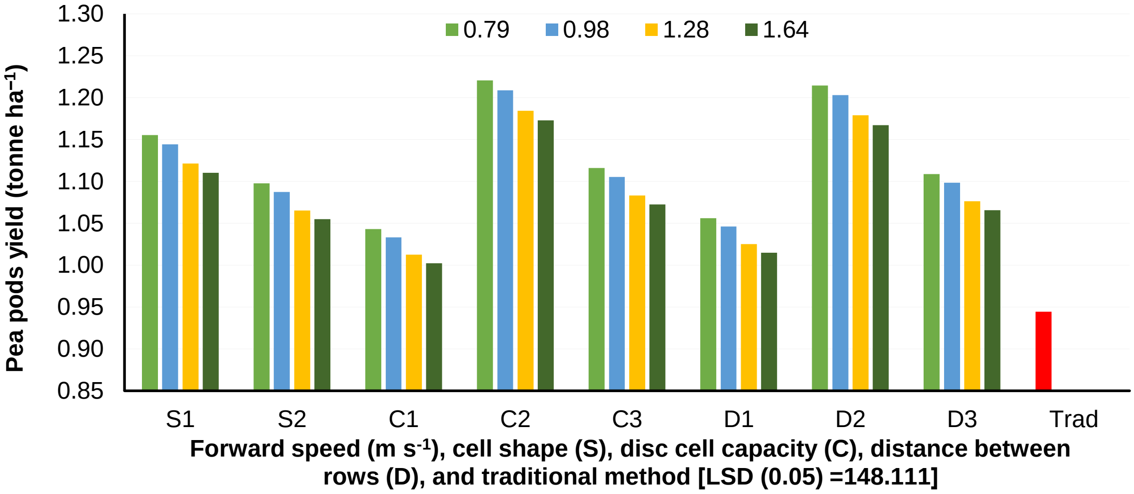

Fig. 10 – Effect of forward speed, cell shape, disc cell capacity, and distance between rows on the pea pods yield

CONCLUSIONS

This study assessed the performance of a new seed drill for planting pea seeds on a raised bed and compared its results with the traditional seeding method; moreover overcomes the shortage of both laborers and the machines that sow pea seeds on a raised bed. The results revealed that the lowest fuel consumption rate and slip ratio was achieved at an operating forward speed of 0.79 m s^{-1}. The lowest seed damage percentage of 1.45% and lowest longitudinal scattering of 12.5% were recorded at a forward speed of 0.79 m s^{-1}, a circular cell shape (S1), and a disc cell capacity of one seed (C1). Furthermore, the highest germination ratio of 96.23% was obtained at a forward speed of 0.79 m s^{-1}, a circular cell shape (S1), disc cell capacity of three seeds (C3), and a distance between rows of 10 cm (D2). The highest pea pod yield was achieved at a forward speed of 0.79 m s^{-1} and disc cell capacity of two seeds (C2). Based on the previous results, it is recommended to operate the seed drill at a forward speed ranging from 0.79 to 0.98 m s^{-1}, using the disc cell capacity of 2 seeds (C2), a circular cell shape (S1), and a distance between rows of 10 cm (D2) to achieve the optimum performance for this seed drill.

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