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Study of some factors affecting a mechanical planting of coated quinoa seeds

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Abstract

This research aim is to study the factors affecting the mechanical planting of coated quinoa seeds. The tested parameters of mechanical planting of coated quinoa seeds are metering-device and forward speeds on seed damage and discharge, seed germination and emergence, missing hills and double plants percentage, planter ground-wheel slip and quinoa-seed yield. The main results in this study can be summarized in the following points: The maximum quinoa coated-seed discharge of 5.50 kg/feddan (feddan = 4200 m² = 0.420 hectares = 1.037 acres) was obtained with a metering-device speed of 20 rpm. Meanwhile, the minimum quinoa coated-seed discharge of 3.10 kg/feddan was obtained with a metering-device speed of 60 rpm. The maximum quinoa plant-emergence of 75.6 % was obtained with a forward speed of 1.82 km/h. Meanwhile, the minimum quinoa plant-emergence of 63.6 % was obtained with a forward speed of 4.79 km/h. By increasing forward speed from 1.82 to 4.79 km/h the total quinoa seed yield decreased from 850 to 650 kg/feddan.

Keywords: mechanical planting, mechanical seed-coating, quinoa seeds.

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1. Introduction

The quinoa (*Chenopodium quinoa* Willd.) crop is one of the important crops on which many food industries are based and is characterized by a high economic return, so the Ministry of Agriculture is seeking to expand its cultivation. Also, the quinoa crop has a high nutritional value. Quinoa is an energy grain which is rich in natural nutrients that provide the body with energy. The cultivated area of quinoa in Egypt reached about 80 feddan in 2017/2018, producing about 1 to 1.5 tons per feddan (feddan = 4200 m² = 0.420 hectares = 1.037 acres) (Agricultural Statistics Economic Affair Sector, the Ministry of Agriculture, 2019). Seeds vary greatly in size, shape, and color. As a rule, seed size is little or unpredictable, making singularization and accurate position troublesome. Likewise, seeds ought to be shielded from a scope of irritations that assault germination seeds or seedlings. Seed-coating innovations can be utilized for mechanical planting to accomplish consistency of plant dispersing and can go about as a transporter for plant protectants. Along these lines, materials can be applied in the objective zone with insignificant interruption to the dirt nature and climate (Taylor *et al*., 1998). Film coating is routinely performed invented or perforated pans on a large-scale basis either on a batch or continuos system (Halmer, 1998; Robani, 1994) and plans are economically accessible that are prepared to utilize fluids or ready as dry powders (Ni, 1997). Utilization of the film-shaping blend brings about uniform testimony of material on each seed with little variety among seeds (Halmer, 1998). The shaped film might go about as an actual boundary, which has been accounted for to lessen the draining of inhibitors from seed covers and may limit oxygen dissemination to the embryo (Duan and Burris, 1997). Film coating is regularly acted invented or punctured skillet for an enormous scope premise either on a clump or continuos framework (Halmer, 1998; Robani, 1994). Film coating is adaptable as a coating framework or a segment of a coating framework (Halmer, 1998; Robani, 1994). Film coating is versatile as a coating system or a component of a coating system. Colorants as stylish appeal to seeds, serve to shade code various verities, and increment the perceivability of seeds in the wake of planting. Film-coated seeds have better stream qualities in the grower (Hill, 1997) because of decreased grinding between seeds. Film coating provides an ideal method for the application of chemical and/or biological seed treatments (McGee, 1995; Taylor *et al*., 1994). El-Habbal *et al*. (1995) proved that coating quinoa seeds with fertilizer containing Fe, Mn, and Zn (2:1:2 by weight) at the rate of 6.5 g/kg seeds gave significant increments in several spikes/plant, grain mass/plant, and both grain and straw yields/took care of. coating machine for quinoa seeds was: coating-unit speed of 28 rpm, coating temperature of 30°C, coating time 15 min, Arabic-gum temperature and concentration 50 to 70 °C and 25 to 75 %, coating with “Fe + Zn + Cersan” and seed-batch mass 2.5 kg. The results obtained at optimum conditions of quinoa were seed germination of 65.3 %, the coating-machine capacity of 4.2 kg/h, specific energy of 5.8 kW.h/ton seeds coated and costs of 10.63 L.E./h and 2725.6 L.E./ton. Karayel (2011) found that by speeding up from 1 to 2 m/s the mean soybean seeds dividing expanded from 99 to 104 mm and exactness dispersing expanded from 19.7 to 29.8 %, the miss list of soybean seeds expanded from 8.2 to 25.9 %, the different lists diminished from 15.7 to 6.9 % and the mean profundity diminished from 51 to 43 mm and the coefficient of variety of profundity to increment from 14.7 to 18.9 %. Barut (2008) contemplated the seed coating and culturing consequences for quinoa stand foundation and grower execution for single seed planting. The results showed that seed prescriptions altogether influenced plant rise date, level of rising consistency, and cultivator execution in single seed planting of quinoa. The coating deferred seed germination, hence, the exposed quinoa seeds had the fastest rise and the greatest level of rising. The quality of feed index, multiple indexes, and precision of the coated seeds were better in terms of quality of feed index, multiple indexes, and precision depending on coating material. The precision was 16.25 % to 19.19 %, indicating that the planter performance was better as compared to the previously published upper limit of 29 %. However, the precision of the planter was better on traditional plots due to proper soil and seed contact. The objective of this investigation is to study the effect of mechanical planting of quinoa coated-seeds such as metering-device and forward speeds on seed damage and discharge, seed germination and emergence, missing hills and double plants percentage, planter ground-wheel slip and quinoa-seed yield.

2. Materials and Methods

2.1 Materials

2.1.1 Seed variety

Quinoa seeds (*Chenopodium quinoa* Willd.) were used in the experimental tests. Table (1) shows some physical properties of quinoa-seeds before and after coating. These data were measured on 100 seeds samples, according to the standards set in (Mohsenin, 1986). The agronomic requirements of quinoa crop are seeds rate of 2.7 to 3.2 and 3.8 to 4.5 kg/feddan for uncoated and coated seeds respectively, number of seed/feddan of 100000 - 120000, row spacing of 70 cm, and distance between seeds of 25 cm. The germination percent of tested quinoa coated seeds was 90.4 %. The tested coating machine: The coating machine used in this study was developed by Abd-Al Fattah *et al*. (2015). Isometric sketch of the coating machine is shown in Figure (1). The main coating machine parts are frame, coating pan, shaft, hot-air dryer, two hinged links and power unit.

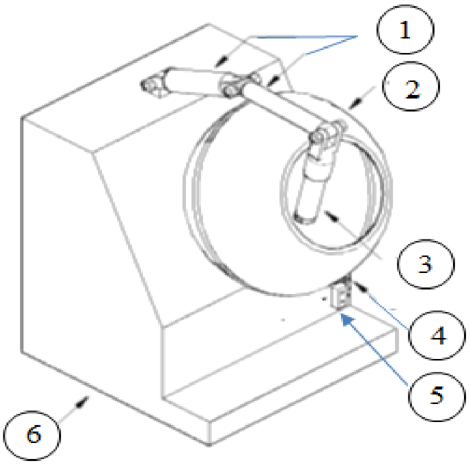
2.1.2 Coating chemical materials

The tested quinoa seeds were coated with Fe, Zn elements and fungicide of “Cersan2 %”. Chemicals’ quinoa-seeds ratio of 5 g/kg was used (Abd-Al Fattah *et al*., 2015). The coating layer needs 0.3:1 wheat flour powder seed ratio (Abd-Al Fattah *et al*., 2015). Arabic gum solution: 75 % concentration was used (Yehia, 2008). Grain batch of 2.5 kg, coating time of 15 minutes, coating temperature of 30°C and coating speed of 28 rpm were used (Mohamed, 2017). Germination test*:* The germination test was conducted by using 100 seeds which was planted in foam bins with 100 cells, temperature range from 37.9 to 40°C. The seed germinations were measured after 7-10 days at different tested parameters (Abd-Al Fattah *et al*., 2015).

Table (1): Physical properties of quinoa-seeds before and after coating at optimum parameters of batch mass of 2.5 kg, coating-unit speed of 28 rpm, coating temperature of 30 ^{0}C, coating time of 15 minutes and coating with "Fe + Zn + Cersan".

Properties		Before coating				After coating			
		Maximum	Minimum	Average	Coefficient of variation	Maximum	Minimum	Average	Coefficient of variation
The mass of 1000 kernel		24.5	25.6	25.0	0.38	50.7	42	46.3	6.15
Real density (kg/m³)		410	395	402.5	10.6	475	425	450	35.3
Bulk density (kg/m³)		385	375	380	7.7	445	400	422.5	31.8
Dimensions	Length (mm)	3.35	3.25	3.3	0.07	4.95	4.55	4.75	0.28
	Width (mm)	3.64	3.45	3.5	0.13	3.90	3.43	3.6	0.33
	Thickness (mm)	2.25	2.15	2.2	0.07	2.60	2.42	2.51	0.12
Volume (mm^3)		27.4	24.1	12.7	2.3	50.19	37.7	43.7	8.8
Projected area (mm^2)		12.1	11.2	11.6	0.6	19.30	15.60	17.4	2.6

The germination percent of tested quinoa coated seeds was 90.4 %.

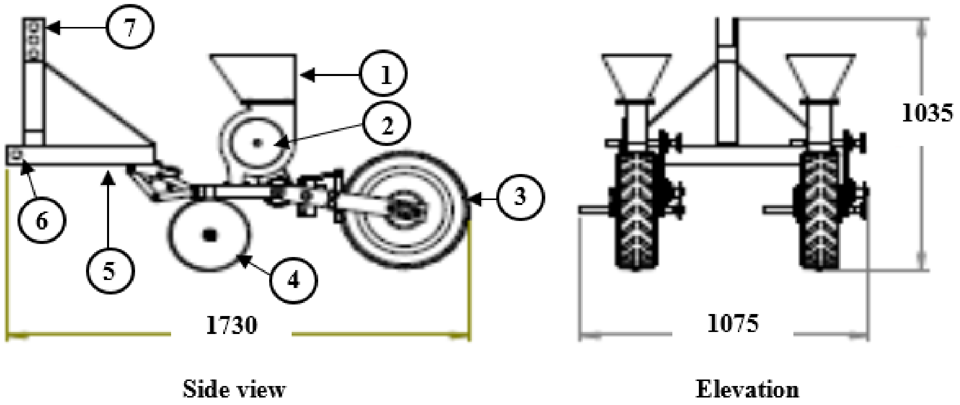


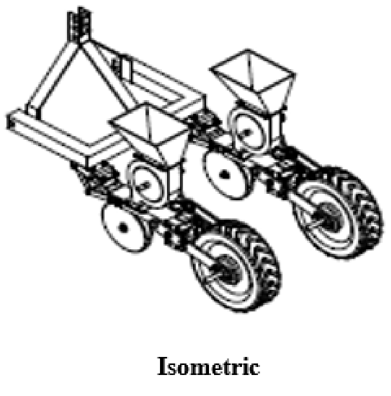
No.	Part name
1	Two hinged links
2	Coating unit
3	Hot air dryer
4	Switch
5	Plug
6	Frame

Figure (1): Isometric sketch of the seed-coating machine (Abd-Al Fattah *et al*., 2015).

2.1.3 Mechanical planter

The tested mechanical planter consists of the main frame with the tool bar and three hitching points and two planting units. Each planting unit consists of the following parts: seed box, seed cutoff, metering-device housing, metering device, transmission system, frame, furrow opener and press wheel (coating device). Figure (2) shows the mechanical planter (Sabry, 2018). Transmission system: The transmission system consisted of chain and sprockets. The transmission ratio between drive wheel (press wheel) and metering- device shaft was 1:0.7. The diameter of drive pressing wheel is 470 mm. Tractor: Kubota of 22.4 kW (30 hp) was used for operating the planter.





No.	Part name
1	Seed box
2	Metering device
3	Press wheel
4	Double disc furrow opener
5	Tool bar
6	Two lower hitching points
7	Upper hitching point

All dimensions are in mm.

Figure (2): Elevation, side view and isometric of the tested planter (Sabry, 2018).

2.2 Methods

2.2.1 Laboratory tests

Primary tests were carried out to choose the studied-parameter ranges. Laboratory experiments were conducted to optimize the metering-device speed**:** Five metering-device speeds of 20, 30, 40, 50 and 60 rpm (0.21, 0.31, 0.42, 0.52 and 0.63 m/s) were tested. To optimize the laboratory parameters, the following indicators were taken into consideration. Seeds discharge: The seed discharge was measured by rotating the press wheel. The fed seeds were collected in plastic bags during a certain number of feeding shaft revolutions and consequently seeds discharge was determined. Seeds damage: For the previously mentioned factors, the damaged seeds including any significant bruising, skin removal or crushing were sorted manually and counted. The damage of seeds after passing through the metering device was calculated by the following equations (Yehia, 1993):

$$\text{Seed damage }\% = \frac{\text{No. of damaged seeds}}{\text{Total No. of seeds}} \times 100 \qquad (1)$$

2.2.2 Field experiments

Field experiments were carried out at Shandawell Research Station, Agricultural Research Center, Sohag governorate, Egypt. Primary tests were carried out to choose the studied-parameter ranges. The mechanical analysis of the experimental soil was classified as a sandy soil. Four forward-speeds of 1.82, 2.97, 3.84 and 4.79 km/h (metering device speeds of 14, 24, 30 and 38 rpm and ground wheel speeds of 21, 34, 44 and 55 rpm) were tested. To optimize the field parameters, the following indicators were taken into consideration. Longitudinal plant-distribution: The longitudinal plant-distribution was analyzed to determine the coefficient of variation (CV) of seeds spacing according to the following formula **(**Yehia, 1993):

$$\text{CV, }\% = \frac{\text{SD of } \mathit{seeds} \text{ spacing}}{\text{Recommended } \mathit{seeds} \text{ spacing}} \times 100 \quad (2)$$

$$\text{SD} = \sqrt{\left(\sum(\text{Plant spacing} - \text{Recommended seeds spacing})^2\right)/\text{n}} \qquad (3)$$

Where: SD is the standard deviation. n is number of seed spacing. Recommended seed-spacing = 25 cm for quinoa seeds.

Emergence percentage: The number of plants per meter of the row was counted for the four tested speeds (1.82, 2.97, 3.84 and 4.79 km/h) to determine emergence percentage according to the following formula*:*

$$\text{Emergence percentage} = \frac{\text{Germinated seeds}}{\text{Total seeds}} \times 100 \quad (4)$$

Missing hills percentage or index: Missing-hills percentage or index indicates that the incapability of seed metering unit to drop even a single seed within the desired range of seed spacing. Missing percentage or index is the indicator of how often the seed skips at the desired spacing. It is the percentage of spacing greater than 1.5 times the theoretical spacing. The missing-hill percentage or index was calculated according to the following formula (Grewal, 2014):

$$\text{Missing hills} = \frac{\text{Number of missing plantsinmeter}}{\text{Total plants in meter}} \times 100 \quad (5)$$

Double plants percent or multiple index: Multiple indexes includes two or more seeds picked and dropped by the seed metering device by a single cell in the metering wheel. The multiple indexes are an indicator of more than one seed dropped within a desired spacing. It is the percentage of spacing that are less than or equal to half of the theoretical spacing. The objective is to minimize the multiples to save costly seeds and to subsequently reduce the labor required for thinning the extra plant population (Grewal, 2014).

$$\text{Double plants} = \frac{n_1}{N} \times 100 \quad (6)$$

Where: n_1 = Number of spacing that are less than or equal to half of the theoretical spacing in the given observations and N = Total number of observations.

Slippage percent: Slip of ground (press) wheel were estimated for four forward-speeds. Slippage percentage was calculated by using the equation (Awady, 1992).

$$\text{Slippage (\%)} = \frac{\text{Actual distance} - \text{Theoretical distance}}{\text{Theoretical distance}} \times 100 \quad (7)$$

$$\text{Theoretical distance} = \text{No. of wheel revolutions} \times \pi \times \text{wheel diam}$$

Final yield: Two rows of quinoa crop with 20 m length for each forward speed were harvested by manual tool and dried in open air (the drying time of 20 day) and threshed and weighed by analog balance and the yield was calculated according to the following formula (Yehia, 1993):

$$\text{Yield (kg/feddan)} = \frac{\text{Mass (kg)}}{\text{Area (feddan)}} \quad (8)$$

Effective field-capacity: Four speeds were used during the field experiments. Times were recorded for the following operations: planting; turning; filling and adjusting to calculate field capacity by using the equation (Yehia, 1993).

$$F.C_{ef} = \frac{60}{T_u + T_i} \text{feddan/h} \quad (9)$$

Where: $F.C_{ef}$ = Effective field-capacity (feddan/h), T_u = The utilized time per feddan (minutes). T_i = The summation of the lost times per feddan (minutes), $T_i = T_1 + T_2 + T_3$, T_1 = Time of repairing (minutes), T_2 = Filling and adjusting time (minutes), and T_3 = Turning time (minutes).

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

$$\eta_f = \frac{F.C._{act.}}{F.C._{th.}} \times 100\% \quad (10)$$

Where: η_f = Filed efficiency (%), $F.C._{act.}$ = Effective field-capacity (feddan/h) and $F.C._{th.}$ = Theoretical field-capacity (feddan/h).

Required power: Required power was calculated by using the following formula (Hunt, 1983).

$$P = 3.23\ Fc \quad (11)$$

Where: P = Power requirements (kW) and Fc = The fuel consumption (L/h).

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

$$\text{Specific energy (kW.h/feddan)} = \frac{\text{Required power(kW)}}{\text{Actual field capacity(fed./h)}} \quad (12)$$

3. Results and Discussion

3.1 Laboratorial experiments

Laboratory experiments were carried out to study the effect of metering-device speed on the performance of the metering-device for quinoa coated-seeds. Laboratory experiments help to adjust the machine under the optimum conditions for the filed experiments.

3.1.1 Effect of metering-device speed on quinoa coated-seed discharge

Figure (3) shows the effect of metering-device speed on quinoa coated-seed discharge. Data show that seed discharge decreased by increasing metering-device speed for quinoa coated-seeds. The maximum quinoa coated-seed discharge of 5.50 kg/feddan was obtained with metering-device speed of 20 rpm. Meanwhile, the minimum quinoa coated-seed discharge of 3.10 kg/feddan was obtained with metering-device speed of 60 rpm. Data shows that by increasing metering-device speed from 20 to 60 rpm the quinoa coated-seed discharge decreased by 43.6 %. The decreasing of coated seed discharge by increasing metering device speed May be due to the time is not enough to fill all cells of metering-device wheel.

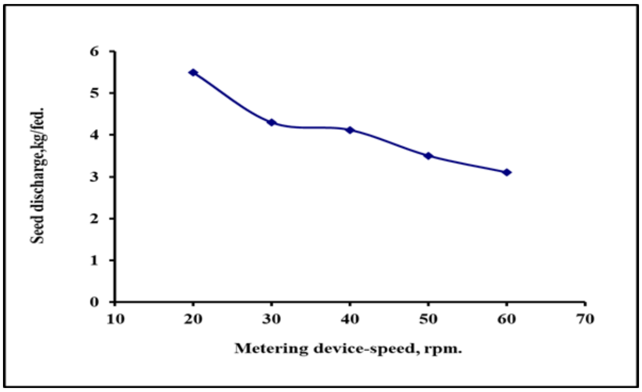


Figure (3): Effect of metering-device speed on quinoa coated-seeds discharge.

3.1.2 Effect of metering-device speed on coated-seed damage

Figure (4) shows the effect of metering-device speed on quinoa coated-seeds damage. Results show that seed damage increased by increasing metering-device speed. The maximum quinoa coated-seeds damage of 4.22 % was obtained with metering-device speed of 60rpm. Meanwhile, the minimum quinoa coated-seeds damage of 0.55 % was obtained with metering-device speed of 20 rpm. The increase in coated-seed damage by increasing metering device speed from 20 to 60 rpm is due to the increased momentum of seeds (momentum = mass × velocity) and increasing impact force accordingly.

3.1.3 Effect of metering-device speed on coated-seed germination

Figure (5) shows the effect of metering-device speed on quinoa coated-seeds germination. Results show that coated-seed germination decreased by increasing metering-device speed. The maximum quinoa coated-seeds germination of 90.4 % was obtained with metering-device speed of 20 rpm. Meanwhile, the minimum quinoa coated-seeds germination of 75.6 % was obtained with metering-device speed of 60 rpm.

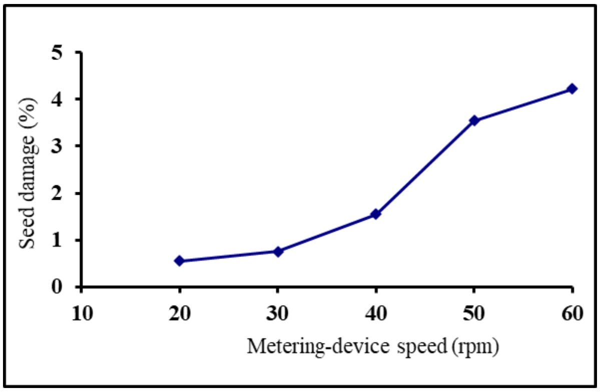


Figure (4): Effect of metering-device speed on quinoa coated-seed damage.

Data shows that by increasing metering-device speed from 20 to 60 rpm the quinoa coated-seeds germination decreased by 16.6 %.

3.2 Field experiments

3.2.1 Effect of forward speed on planter performance

3.2.1.1 Plant emergence

Figure (6) shows the effect of forward speed on quinoa plant emergence. Results show that plant emergence decreased by increasing forward speed. The maximum quinoa plant-emergence of 75.6 % was obtained at forward speed of 1.82 km/h. Meanwhile, the minimum quinoa plant-emergence of 63.6 % was obtained with a forward speed of 4.79 km/h. Data shows that by increasing forward speed from 1.82 to 4.79 km/h the quinoa plant emergence decreased by 15.9 %.

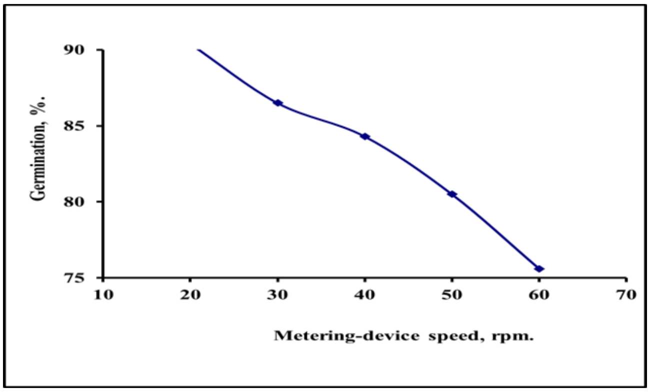


Figure (5): Effect of metering-device speed on quinoa coated seed germination.

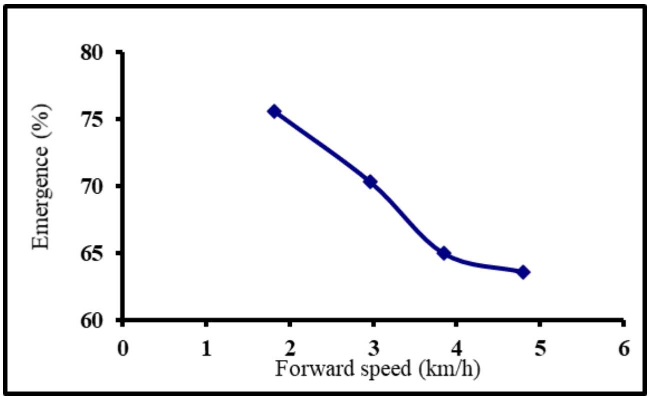


Figure (6): Effect of forward speed on quinoa plant-emergence.

3.2.1.2 Longitudinal plants-distribution and plant scattering

The plants distribution was analyzed in order to determine the frequency, average and coefficient of variation (CV) of quinoa plant-spacing. A low CV represents a row with more uniform seed spacing, and vice versa. Table 2 shows average and CV of quinoa plant-spacing. The optimum conditions clarify that the forward speed of 2.97 km/h had the best longitudinal seed distribution “average quinoa plant-spacing of 9.4 cm, and CV of 6.3 %”. The increase of plant scattering by increasing forward speed may be due to increasing ground-wheel slip in addition to the increase of machine vibration (Table 2).

3.2.1.3 Missing hills and double plants index

Figure (7) shows the effect of forward speed on missing hills and double quinoa plants. Missing hills increased with increasing forward speed. Double plants decreased with increasing forward speed. Data shows that by increasing forward speed from 1.82 to 4.79 km/h the missing-hills percent or index increased from 1.50 to 4.9 %. Data shows that by increasing forward speed from 1.82 to 4.79 km/h the duple-quinoa-plant percent or index decreased from 22.4 to 2.10 %. The increasing of missing hills and decreasing of double plants by increasing forward speed is due to increasing ground wheel slip.

Table (2): Effect of forward speed on average and C.V. of quinoa plant spacing.

Plant spacing	Forward speed (km/h)			
	1.82	2.97	3.84	4.79
Average (cm)	8.5	9.4	12.4	13.6
CV	5.2	6.3	7.5	7.9

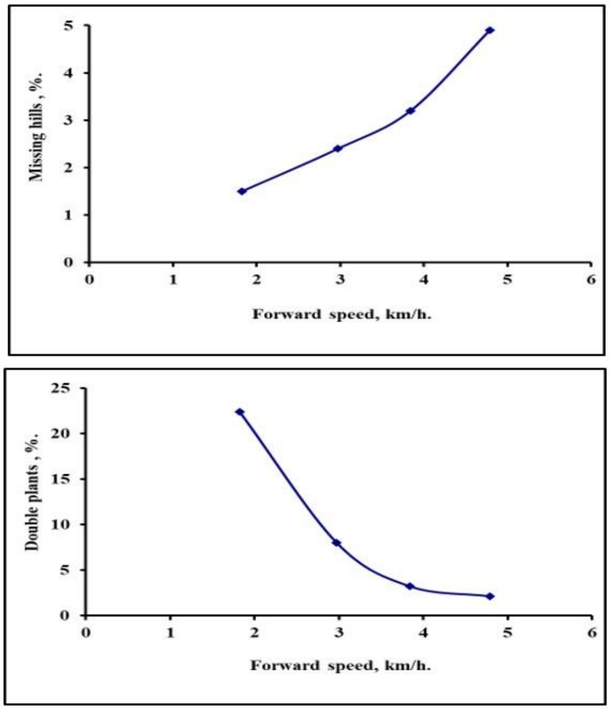


Figure (7): Effect of forward speed on missing hills and double quinoa plants.

3.2.2 Effect of forward speed on ground-wheel slip percent

Figure (8) shows the effect of forward speed on ground-wheel slip percent. The ground-wheel slip increased by increasing forward speed. The maximum slip of 8.10 % was obtained with the forward speed of 4.79 km/h. Meanwhile, the minimum slip of 4.76 % was obtained with the forward speed of 1.82 km/h.

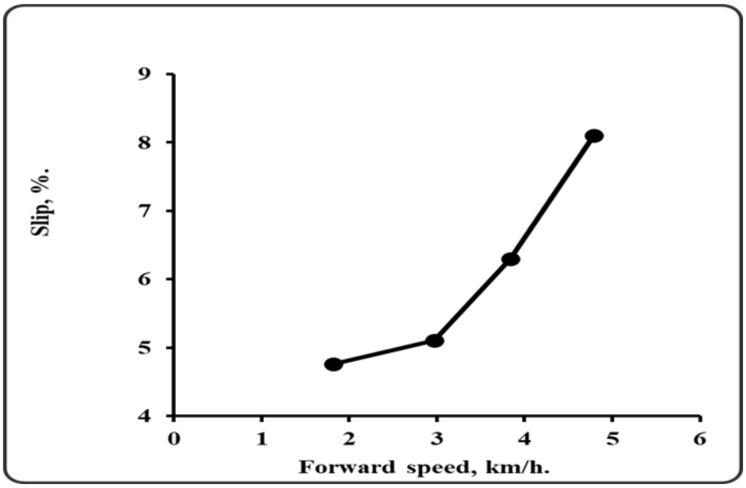


Figure (8): Effect of forward speed on ground-wheel slip percent.

3.2.3 Effect of forward speed on quinoa seed yield

Figure (9) shows the effect of forward speed on quinoa seed yield. The seed yield decreased with increasing forward speed. Data shows that by increasing forward speed from 1.82 to 4.79 km/h the total quinoa seed yield decreased from 850 to 650 kg/feddan. The decrease in crop yield by increasing forward speed is due to the low plant emergence resulting from high ground-wheel speed (metering-device speed) and also due to decreasing of longitudinal plant distribution.

3.2.4 Effect of forward speed on effective field capacity and efficiency

Figure (10) shows the effect of forward speed on effective field capacity and field efficiency. The effective field capacity increased and field efficiency decreased with increasing forward speed. The maximum effective field capacity of 0.86 feddan/h was obtained with the forward speed of 4.79 km/h. Meanwhile, the minimum effective field capacity of 0.43 feddan/h was obtained with the forward speed of 1.82 km/h. The maximum field efficiency of 81.83 % was obtained with the forward speed of 1.82 km/h.

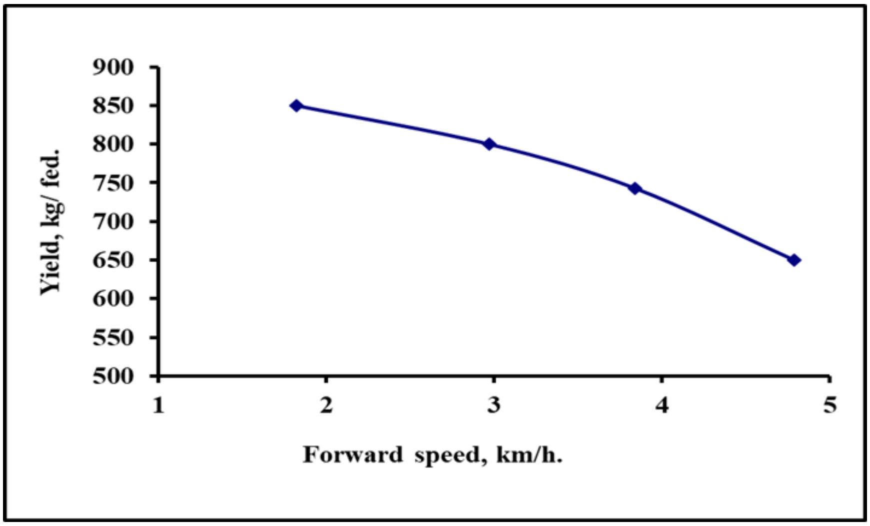


Figure (9): Effect of forward speed total quinoa seed-yield.

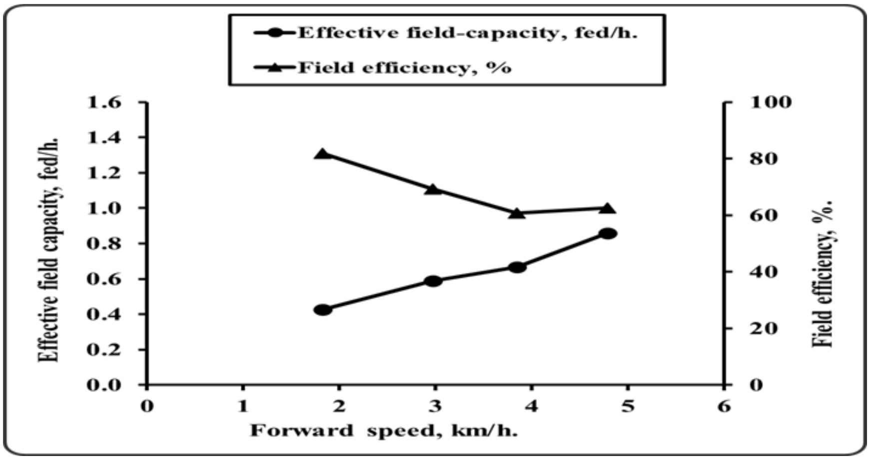


Figure (10): Effect of forward speed on effective field capacity and field efficiency.

Meanwhile, the minimum field efficiency of 62.63 % was obtained with a forward speed of 4.79 km/h. Decreasing field efficiency by increasing forward speed is due to decreasing time losses.

3.2.5 Effect of forward speed on required power and specific energy

Figure (11) shows the effect of forward speed on required power and specific energy. Required power and a specific energy for operating the mechanical planter increased with increasing forward speed. By increasing forward speed from 1.82 to 4.79 km/h required power increased from 1.90 to 5.00 kW and specific energy increased from 4.46 to 5.83 kW.h/feddan. The required power and specific energy of 5.0 kW and 5.83

kW.h/feddan were obtained with forward speed of 4.79 km/h. Meanwhile, the minimum required power and specific energy of 1.90 kW and 4.46 kW.h/feddan were obtained with the forward speed of 1.82 km/h.

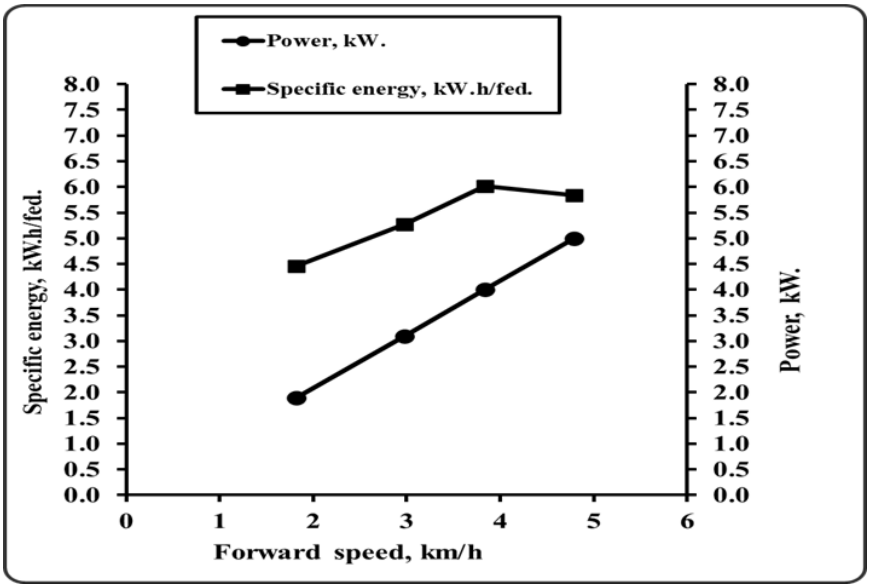


Figure (11): Effect of forward speed on power and specific energy.

4. Conclusion

The optimum forward speed of tested planter for quinoa coated-seeds was 1.82 km/h. The results obtained at optimum forward speed were plant emergence of 88.4 %, missing hills of 1.50 %, double plants of 22.4, average plant spacing of 25 cm, effective field-capacity of 0.43 fed/h, field efficiency of 81.83%, seed yield of 887 kg/feddan, press-wheel slip of 4.76 %, power of 3.1 kW, specific energy of 4.53 kW.h/feddan.

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