RESEARCH ARTICLE

DEVELOPMENT OF A METERING DEVICE FOR DRILLING WHEAT GRAINS IN HILLS

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Manuscript Info	*Abstract*
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The aim of this investigation is to develop and evaluate a metering device for drilling wheat grains in hills. The developed metering device is a single sided flanged-disc with 4 cells. Three cell-sizes with 3-4, 5-6 and 7-8 grain/cell, four forward speeds of 2, 4, 6 and 8 km/h were investigated. The main results in this study can be summarized in the following points:The maximum seeding rate of 72.52 kg/fed was obtained at ground-wheel speed of 20 rpm or metering-device speed of 83.3 rpm and cell size of 7-8 grain/cell. Meanwhile, the minimum seeding rate of 34.39 kg/fed was obtained at ground-wheel speed of 60 rpm or metering-device speed of 333.3 rpm and cell size of 3-4 grain/cell.For designed metering device, the maximum wheat-grains germination of 100 % was obtained at ground-wheel speed of 20 rpm or metering-device speed of 83.3 rpm and cell size of 7-8 grain/cell. Meanwhile, the minimum wheat-grains germination of 98.7 % was obtained at metering-device speed of 60 rpm and cell size of 3-4 grain/cell.For designed metering device, the maximum wheat-plant emergence of 96.6 % was obtained at forward speed of 2 km/h and cell size of 7-8 grain/cell. Meanwhile, the minimum wheat-plant emergence of 90 % was obtained at forward speed of 8 km/h and cell size of 3-4 grain/cell.The optimum conditions clarify that the forward speed of 2 km/h had the best longitudinal seed distribution: average wheat hill-spacing of 11 cm, and CV of 5.4 %.The minimum missing-hills percent of 2.1 % was obtained with forward speed of 2 km/h. Meanwhile, the maximum missing-hills percent of 6.7 % was obtained with forward speed of 8 km/h.For designed metering device (hill drilling), the maximum wheat-grain yield of 3.465 Mg/fed (ton/fed) was obtained with forward speed of 2.0 km/h and cell size of 7-8 grain/cell. Meanwhile the minimum wheat-grain yield of 2.715 Mg/fed was obtained with forward speed of 8 km/h and cell size of 3-4 grain/cell.

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Introduction:-
Grain drilling is very important in saving hand labor, improving production, and allowing further mechanization.

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Astudy byAbou-Sabe, 1956 showed that the right placement of seed gives an increase of 10 % in yield crop. Sharma *etal*. (1983) stated that the use of seed drill gives an increase of 12.5 % in wheat yield and it reduces the time required for sowing by 40 %. Beside this, uniform placement of seed saves about 50 % of its quantity.

The wheat is most important crop in Egypt. Total area of wheat crop in Egypt in year of 2018 is 1.342805 million ha. the grain production is 8.8 million ton "yield is 65534 hg/ha" (FAO, 2018).

Wheat yield improved by 10 % with appropriate diversity, production costs could decrease by 20 to 30 %, and irrigation water requirements could be reduced by up to 35% compared to conventional planting on flat soils [Wang Fahong*etal*. (2004) and Roth *etal*. (2005)].

The United Nations Development Program (2013) stated that wheat is usually grown either by drilling seeds in rows while maintaining a distance from row to row 15 cm or by manually transmitting seeds to a flat surface of flat soil and then incorporating them through shallow tillage after planting and flood irrigation.

Awady*etal*. (2001) developed and tested a Pakistany "Naeem" seed-drill. It was found that at different gate-openings 10, 20, 30, and 40 mm, discharge decreased by 4.94, 2.55, 1.29, and 0.8 % respectively, when the speed was increased from 20 to 50rpm (from 0.097 to 0.259 m/s feeder speed). Awady*etal*. (1997a) concluded that seed discharge slightly decreases as the speed of ground wheel increased. This is believed to be due to insufficient time available for seeds in the flute to move and replace the continuously discharging seeds. Discharge varied between ± 0.0027 - 0.013 %. The seed discharge is directly proportional to the gate opening area.

Jat*etal*. (2004) reported that due to the uniform planting distribution cross sowing reduced the weed growth rate and yields and their characteristics increased. They added that farmers tend to plant wheat in the hills on the ridges.

Satoshi *etal*. (2000) studied the effects of the number of seeds on the yield components and yield, he found that when the number of seeds increases, the number of seeds per square meter increases significantly and the number of seeds per plate decreases, indicating the inverse nature of these two characteristics. The results of this experiment showed the positive effects of the number of seeds per panicle on yield making up for the decreasing panicle number.

Lack (2012) studied the effects of seed number per hill on the yield (2, 4, 6 and 8) and he found that the highest yield was obtained from 6 seeds per hill. Satti*etal*. (2012) stated that the wheat break angle is absolutely necessary for the design of the seed box of the planting machine. It is suggested that the angel ranged between 26-30 degrees.

Ibrahim *etal*. (2008) develop a seed drill device to grow complex and drenched seed rice in rows. The results showed that the weed plants decreased by square meter and the germination rate increased by 97% at a forward speed of 0.64 m / s.

Awad (2016)developed and evaluated a planter to plant wheat grains in hills. It is found that the optimum parameters were: forward speed of 1.21m/s, and cell size of metering device of 8 grain/cell. The results at optimum parameters were: wheat-grain yield of 2.9 Mg/fed, plant emergence of 97.78%, specific energy of 3.01 kW/fed and machine operation-cost of 59 L.E./fed.

Afify (2009) developed the feeding device for seed drill to suitplanting of medicinal and aromatic seeds in the hills.Four forward speeds and four hills spacing and the continuously spaced were tested. It is concluded that the optimum hills spacing was 30 cm to achieve a higher seed yield of 815 kg/fed, production cost 26.44 L.E/Mg and a higher emergenceof 95.37% with a forward speed of 3.13 km/h.

Awady*etal*. (2000) found that the yield of wheat grain ranged between 3.45-3.14 and between 3.51-3.21 ton/fed for mechanical and pneumatic seed-drill respectively resulted at forward speed range of 2.18-5.46 km/h.
Awady*etal*. (1998a and b) mentioned that the visible seed-damage increased by increasing feeder speed. That is considered due to increasing the momentum changes. The impact force increases by acceleration resulting in visible seed-damage.

The aim of this investigation is to develop and evaluate a metering device for drilling wheat grains in hills to reduce the seed rateperfeddan when planting.

Materials and Methods:-
Materials:
Seed drill:
Seed drill used in this study is "Tye" seed drill. Specifications of the seed drill were:

Made in: Italy.Model: Tye. Type: Mounted.No.of rows:21.Row spacing: 11.9 cm.

Working width: 250 cm.Opener type: Shoe.

Metering device before and after modification:
Internal force feed type seed meters was developed. The metering device before development consists of a plain flanged disc interfered with internal-corrugated ring. The seeding rate can be controlled by the exposed length of internal-corrugated ring by moving the as shown in fig. 1.

Metering device after modification has a single-sided flanged disc with 4 cells. The disc diameter and width are 74 and 22 mm respectively. Each cellhasdepth of 4 mm. The tested cell diameters are 10, 12 and 14 mm (cell sizes are 3-4, 5-6 and 7-8 grain/cell. Fig. 2 shows the metering device after modification.
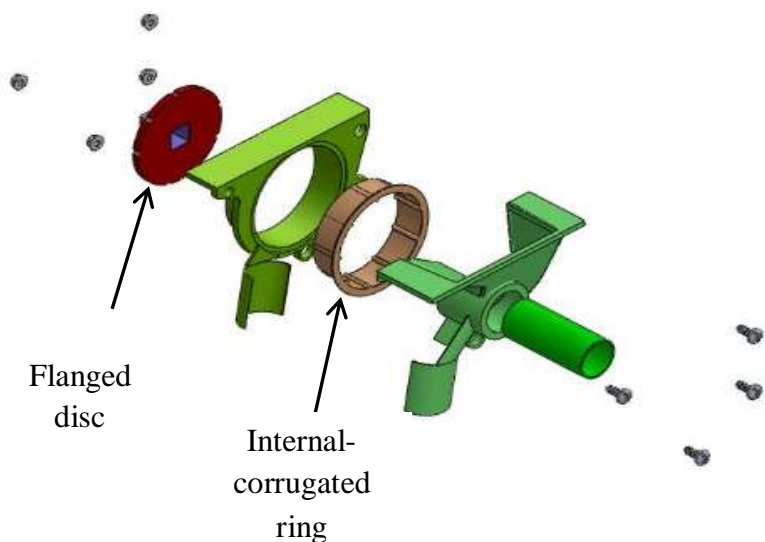

Flanged disc

Internal-corrugated ring

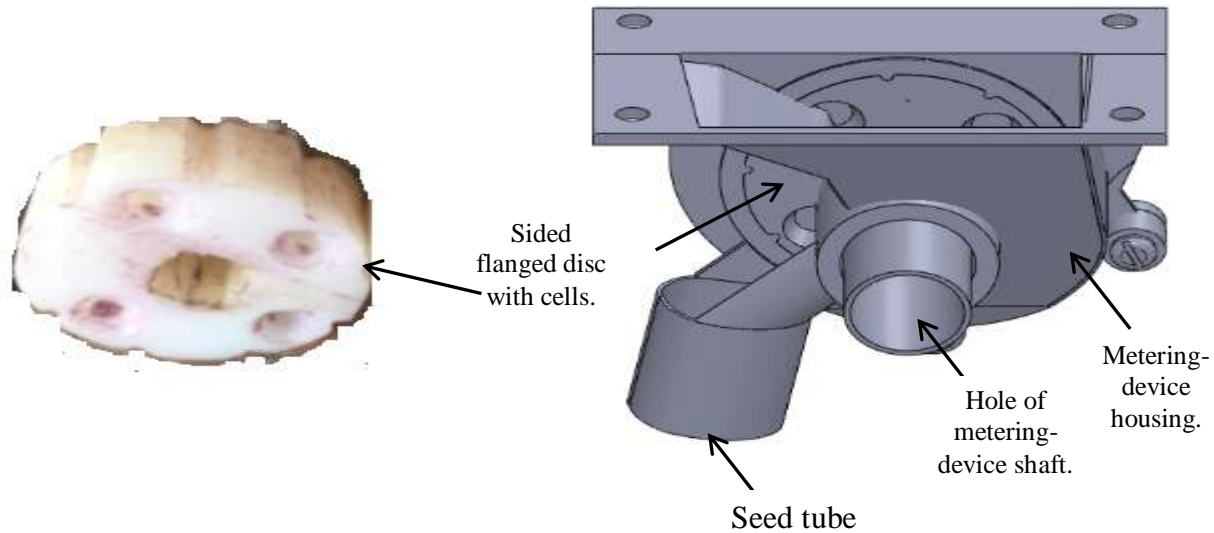**Fig. 1:-** Metering device before modification.

Fig. 2:- Metering device after modification.

Tractor: Tractor used in this study is "Belaruse"with 54.4 kW (74 hp). Specifications of the tractor were:

Model	U MZ-6kme
Source	BelaruseRussa
Engine power	55.18 kW (74 hp)
P.T.O speed	540 r.p.m
Mass	3920 kg
Tiers size : Front Rear	 9 x 20 in 28 x15.5 in
Speed	8 Forward 2 Reverse
Range of speed Low speed High speed	 2.64 -15.3 km/ h 3.85 -27.8 km/ h

Methods:-
Grains used in the investigation:
In the experiments, wheat grains of variety of Sakha 93 was used. The wheat grains were treated by fungicide.
Two experiment-groups were carried out on the effect of some factors on the grain-drill performance as follows:

Laboratory experiments: were carried out to find the factors affecting feed rate, grain damage and germination, and longitudinal grain-distribution. These factors are: ground-wheel speed and number of grains per cell. All treatments were replicated five times to give more reliable averages.

Field experiments: were carried out to determine the following points: emergence percentage, longitudinal grain-distribution, slip of ground wheel, draft force, power, specific energy, field capacity, final grain yield, and estimating the costs of using the machine.

Planting intensity was about 45 kg of wheat seeds per fed for normal drilling. The field experiment included four forward speeds (2, 4, 6, and 8 km/h).

Seed discharge:
seed discharge were measured in laboratory and field tests at different ground-wheel speeds of 10, 20, 30, 40, 50 and 60 rpm or metering-device speeds of 83.3, 166.7, 250 and 333.3 rpm and cell sizes of 3-4, 5-6 and 7-8 grains/cell.

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

Seed damage and germination:
In the previously mentioned factors, the damaged grains were sorted manually and weighed. The percentage seed-damages were calculated, and related to the seed discharge.
One thousand wheat grains were germinated to give the real germination ratio before passing through the feeding device.
The actual germination ratio of seeds after passing through the feeder was calculated by the following equations (Yehia, 1997):

$$\text{Actual germination percent} = \text{Germination \% of unused seeds} - (\text{Visibel seed damage, \%} + \text{invisible seed damage, \%})$$

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

$$\text{Invisible seed damage, \%} = (\text{No. of shoots} \div \text{Total No. of seeds}) \times 100$$

The number of plantings per meter of the row was counted for the four tested- speeds 2, 4, 6, and 8 km/h) to determine the emergence ratio according to the following formula:

$$\text{Emergence ratio} = \frac{\text{Average No. of plants per sq. m}}{\text{Average No. of delivered grains per sq. m}}$$

Longitudinal grain-distribution:
For metering-device speeds, the wheat grains received on 4-meter length metal sheet coated by grease were counted to determine the longitudinal seed-distribution at different previously mentioned-factors.
The seed distribution was analyzed to determine coefficient of variation (CV) of seeds spacing according to the following formula:

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

Where: SD is the standard deviation.

Slip of ground wheel:
It 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).

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

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

Final grain-yield:
The yield of each plot was measured to study the effect of the above-mentioned factors on wheat crop. A frame of 1×1 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 grain 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:

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

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

Field efficiency (η_f):
Field efficiency was calculated using the following equation:

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

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

Draft force and power:
A drawbar 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:

$$F = \frac{\pi}{4} \times (R_1{}^2 - R_2{}^2) \times P$$

Where:
R_1: diameter of piston, (0.04 m), R_2: diameter of connecting rod, (0.018 m) and
P: dynamometer pressure, (N/m^2).

Required power:
Was calculated by using the following formula:
$$\text{Power} = \text{Draft force} \times \text{Forward speed}$$

Specific energy:
Specific energy can be calculated by using the following equation:
$$\text{Specific energy, kW.h/fed} = \frac{\text{Power required, kW.}}{\text{Actual field capacity, fed/h}}$$

Results and Discussion:-
Results of laboratory experiments:
Laboratory experiments were carried out to study the effect of metering-device (ground wheel) speed on the performance of the designed metering-devicefor dibbling wheat grains. Laboratory experiments help to adjust the machine under the optimum conditions during the filed experiments.

Effect of metering-device speed and cell size on grain discharge or seeding rate:
Fig. 3 shows the effect of metering-device speed and cell size on grain-wheat discharge or seeding rate. Results showed that seeding rate decreased by increasing metering-device speed.

The maximum seeding rate of 72.52 kg/fed was obtained at ground-wheel speed of 20 rpm or metering-device speed of 83.3 rpm and cell size of 7-8 grain/cell. Meanwhile, the minimum seeding rate of 34.39 kg/fed was obtained at ground-wheel speed of 60 rpm or metering-device speed of 333.3 rpm and cell size of 3-4 grain/cell.
Results show the maximum wheat seeding-rate for normal grain-drill was 45.78 kg/fed at ground speed of 20 rpm or metering device speed of 4 rpm. Meanwhile, the minimum wheat seeding-rate for normal grain-drill was 43.83 kg/fed at ground speed of 60 rpm or metering device speed of 12 rpm.
Results shows by increasing metering-device speed from 20 to 60 rpm the seeding rate was decreased by about 6 %. The decreasing of wheat-grain discharge by increasing metering device speed is due to the time is not enough to fill all cells of metering-device by seeds.

Effect of metering-device speed and cell size on grain-damage percent:
Fig. 4 shows the effect of metering-device speed and cell size on wheat-grain damage percent. Results showed that grain damage increased by increasing metering-device speed.
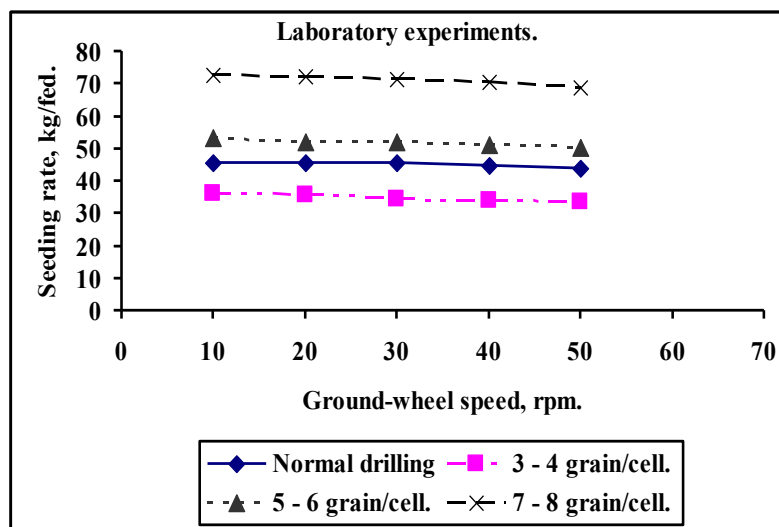

Fig. 3: Effect of metering-device speed and cell size on seeding rate of wheat grains.
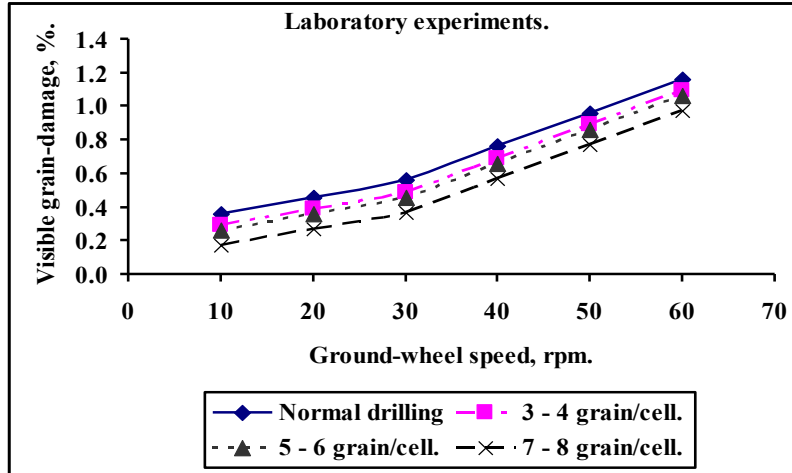
Fig. 4:- Effect of metering-device speed and cell size onvisible damage of wheat grains.

For developed metering device, the maximumwheat-grain damage of 1.09% was obtained at ground-wheel speed of 60 rpm or metering-device speed of 333.3 rpm and cell size of 3-4 grain/cell. Meanwhile, the minimum wheat-grain damage of 0.17 % was obtained at ground-wheel speed of 20 rpm or metering-device speed of 83.3 rpm and cell size of 7 -8 grain/cell.

For normal grain-drill, the maximum wheat-grain damage percent was 1.16 % at ground speed of 20 rpm or metering device speed of 4 rpm. Meanwhile, the minimum wheat-grain damage percent was 0.36 % at ground speed of 60 rpm or metering device speed of 12 rpm.

The increase in grain damage by increasing metering device speed from 20 to 60 rpm is due to increasing momentum of grains (momentum = mass x velocity) and increasing impact force accordingly.

Effect of metering-device speed on wheat-grain germination percent:
Fig. 5 shows the effect of metering-device speed and cell size on wheat-grains germination percent. Results showed that wheat-grain germination decreased by increasing metering-device speed and decreasing of cell size.

For designed metering device, the maximum wheat-grains germination of 100 % was obtained at ground-wheel speed of 20 rpm or metering-device speed of 83.3 rpm and cell size of 7-8 grain/cell. Meanwhile, the minimum wheat-grains germination of 98.7 % was obtained at metering-device speed of 60 rpm and cell size of 3-4 grain/cell.
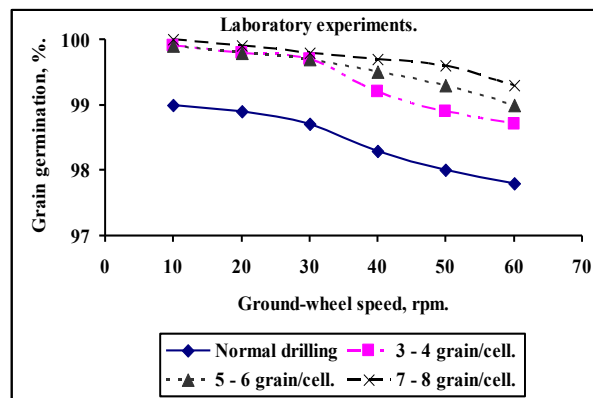
For normal grain-drill, the maximum wheat-grain germination of 99 % was obtained at ground-wheel speed of 20 rpm or metering-device speed of 83.3 rpm and cell size of 7 -8 grain/cell. Meanwhile, the minimum wheat-grains germination of 97.8 % was obtained at metering-device speed of 60 rpm and cell size of 3-4 grain/cell.

Fig. 5: Effect of metering-device speed and cell size on wheat-grains germination.

Results:-
Of field experiments:
Effect of forward speed and cell size on wheat-plant emergence percent:
Fig. 6 shows the effect of forward speed and cell size on wheat plant-emergence. Results showed that plant emergence decreased by increasing forward speed and increasing cell size.

For designed metering device, the maximum wheat-plantemergence of 96.6 % was obtained at forward speed of 2 km/h and cell size of 7-8 grain/cell. Meanwhile, the minimum wheat-plant emergence of 90 % was obtained at forward speed of 8 km/h and cell size of 3-4 grain/cell.

For normal grain-drill, the maximum wheat-plantemergence of 96.6 % was obtained at forward speed of 2 km/h and cell size of 7-8 grain/cell. Meanwhile, the minimum wheat-plant emergence of 90 % was obtained at forward speed of 8 km/h and cell size of 3-4 grain/cell.

The decrease of plant emergence by increasing forward speed is due to the increase of metering device speed and the momentum of seeds which causes seed damage accordingly. Also, planting depth could not be thoroughly adjusted at high speed that tends to decrease plant emergence.
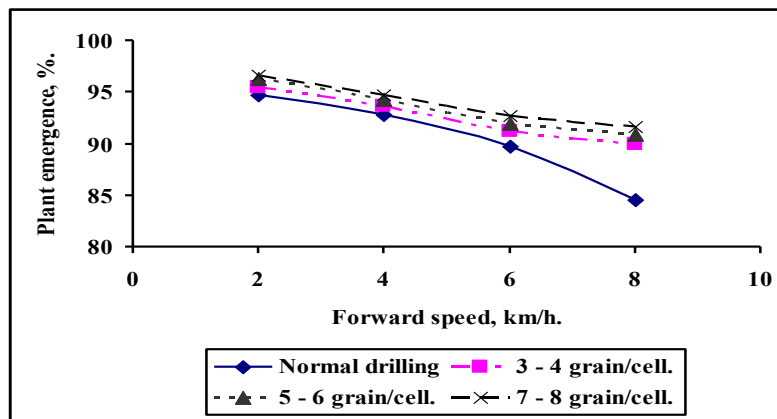

Fig. 6:- Effect of forward speed and cell size on wheat-plantemergence.

Effect of forward speed and cell size on average number of wheat-grains per hill:
Table 1 and fig. 7 show the effect of cell size and forward speed on maximum, minimum and average number of wheat-grains per hill.

Results show that the maximum number of wheat grains per hill of 7 was obtained with cell size of 7-8 grains/cell and forward speed of 2 km/h. Meanwhile, the minimum number of wheat grains per hill of 2 was obtained with cell size of 3-4 grains/cell and forward speed of 8 km/h.

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

Effect of forward speed on longitudinal hill-distribution:
Table 2 and fig. 8 show the effect of forward speed on average and CV of wheathill-spacing.
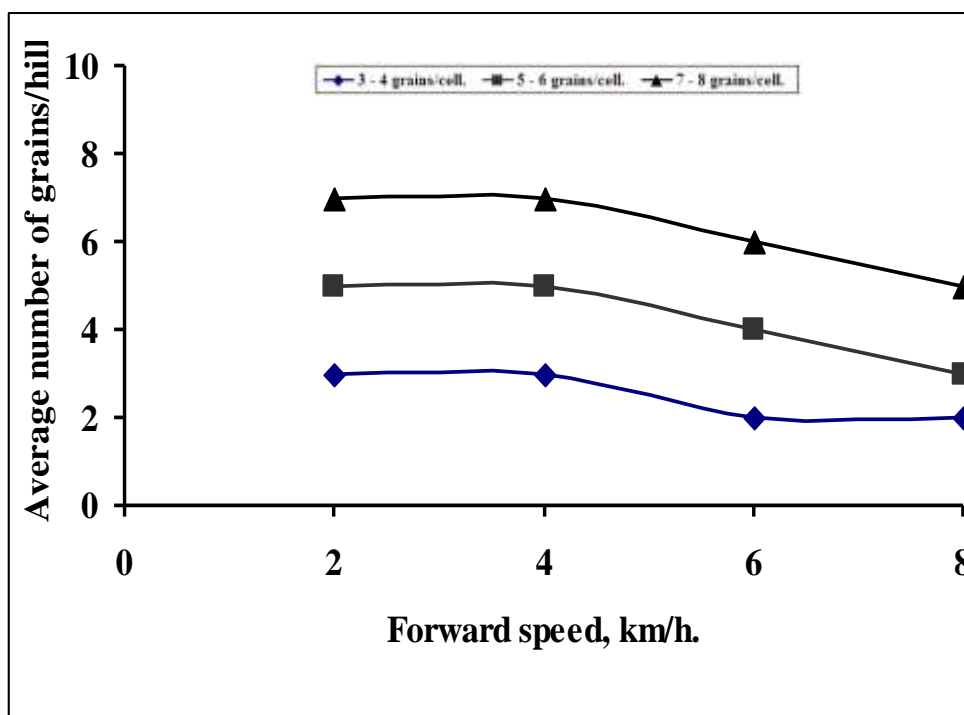
The plants distribution was analyzed in order to determine the frequency, average and coefficient of variation (CV) of wheathill-spacing. A low CV represents a row with more uniform hill spacing.

The optimum conditions clarify that the forward speed of 2 km/h had the best longitudinal seed distribution: average wheat hill-spacing of 11 cm, and CV of 5.4 %.

The increase of hill spacing by increasing forward speed is due to increasing ground-wheel slip in addition to the increase of machine vibration.

Table 1:- Effect of cell size and forward speed on maximum, minimum and average number of wheat-grains per hill.

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.
3 - 4	2	4	2	3	4.3
	4	3	3	3	4.7
	6	2	2	2	5.2
	8	2	2	2	5.6
5 - 6	2	6	4	5	4.6
	4	5	5	5	4.9
	6	5	3	4	5.4
	8	4	2	3	5.6
7 - 8	2	8	6	7	4.4
	4	7	7	7	5.2
	6	6	6	6	5.3
	8	6	4	5	5.7

Fig. 7:- Effect of cell size and forward speed on average number of wheat-grains per hill.

Table 2:- Effect of forward speed on maximum, minimum and average hill-spacing.

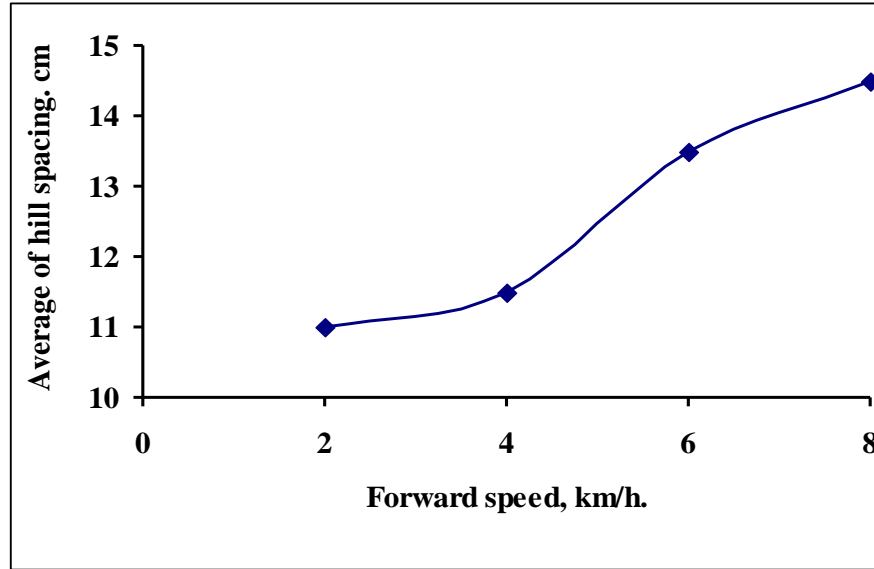| Forward speed, km/h	Max .hill spacing ,cm	Min. hill spacing, cm	Average hill spacing, cm	C.V.
2	12	10	11	5.4
4	13	10	11.5	5.6
6	15	12	13.5	7.8
8	16	13	14.5	11.1

Fig.8:- Effect of forward speed on average hill-spacing of wheat plants.

Effect of forward speed on missing-hills percent:
Fig. 9 shows the effect of forward speed on missing-hill percent of wheat plants.The minimum missing-hills percent of 2.1 % was obtained with forward speed of 2 km/h. Meanwhile, the maximum missing-hills percent of 6.7 % was obtained with forward speed of 8 km/h.

Effect of forward speed and cell size on wheat-grain yield:
Fig. 10 shows the effect of forward speed and cell zize on wheat-grain yield. Wheat-grain yield decreased with increasing forward speed.

For designed metering device (hill drilling), the maximum wheat-grain yield of 3.465 Mg/fed (ton/fed) was obtained with forward speed of 2.0 km/h and cell size of 7-8 grain/cell. Meanwhile the minimum wheat-grain yield of 2.715 Mg/fed was obtained with forward speed of 8 km/h and cell size of 3-4 grain/cell.

For normal drilling, the maximum wheat-grain yield of 2.805 Mg/fed (ton/fed) was obtained with forward speed of 2.0 km/h. Meanwhile the minimum wheat-grain yield of 2.700 Mg/fed was obtained with forward speed of 8 km/h.
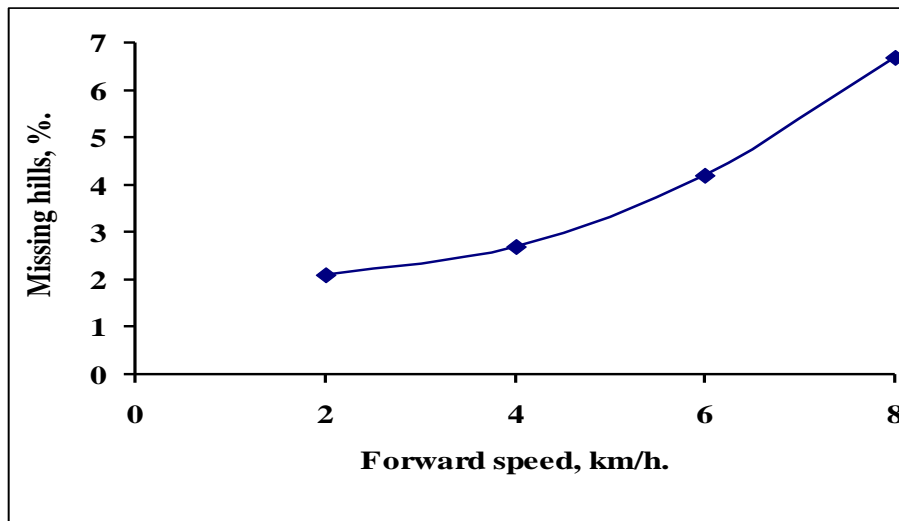

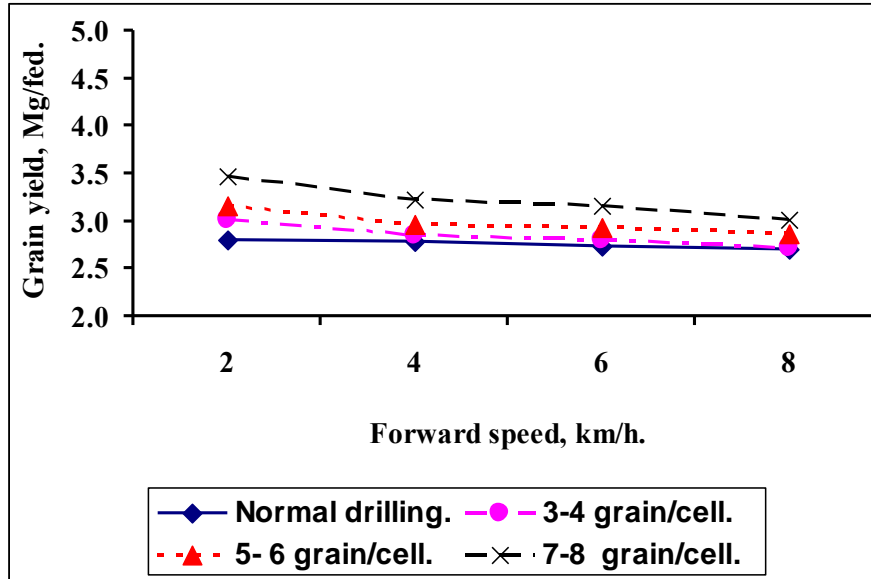**Fig.9:-** Effect of forward speed on missing-hills percent of wheat plants.

Fig. 10:- Effect of forward speed on wheat-grain yield.

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.

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 6.1 % was obtained with forward speed of 8 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.
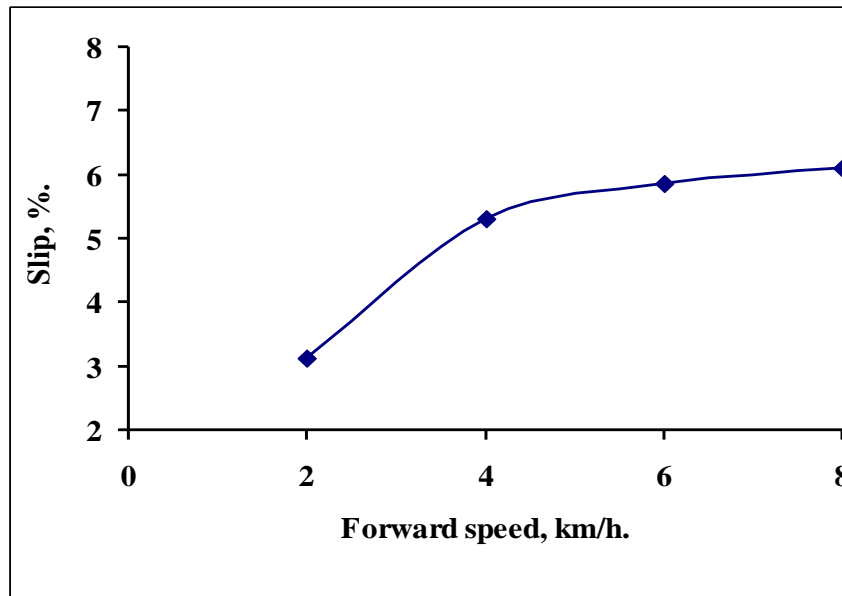

Fig. 11:- Effect of forward speed on ground-wheel slip percent.

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 4,67fed/h and minimum field-efficiency of 77.9 % was obtained with forward speed of 8 km/h.

Meanwhile the minimum field-capacity of 1.35 fed/h and maximum field-efficiency of 89.95 % was obtained with forward speed of 2 km/h.

Effect of forward speed on draft force, required power and specific energy:
Fig. 13 and fig. 15show the effect of forward speed on draft force, required power and specific energy. The maximum draft force, required power and specific energy of 14.9kN, 33.11 kW and 7.08kW.h/fed were obtained with forward speed of 8 km/h. Meanwhile the minimum values of 13.5 k N, 7.5 kW and 5.56kW.h/fed were obtained ta forward speed of 2 km/h.

The variations in draft force and required power with different forward-speed at the same ground-wheel and depth of sowing is due to the increased soil resistance.
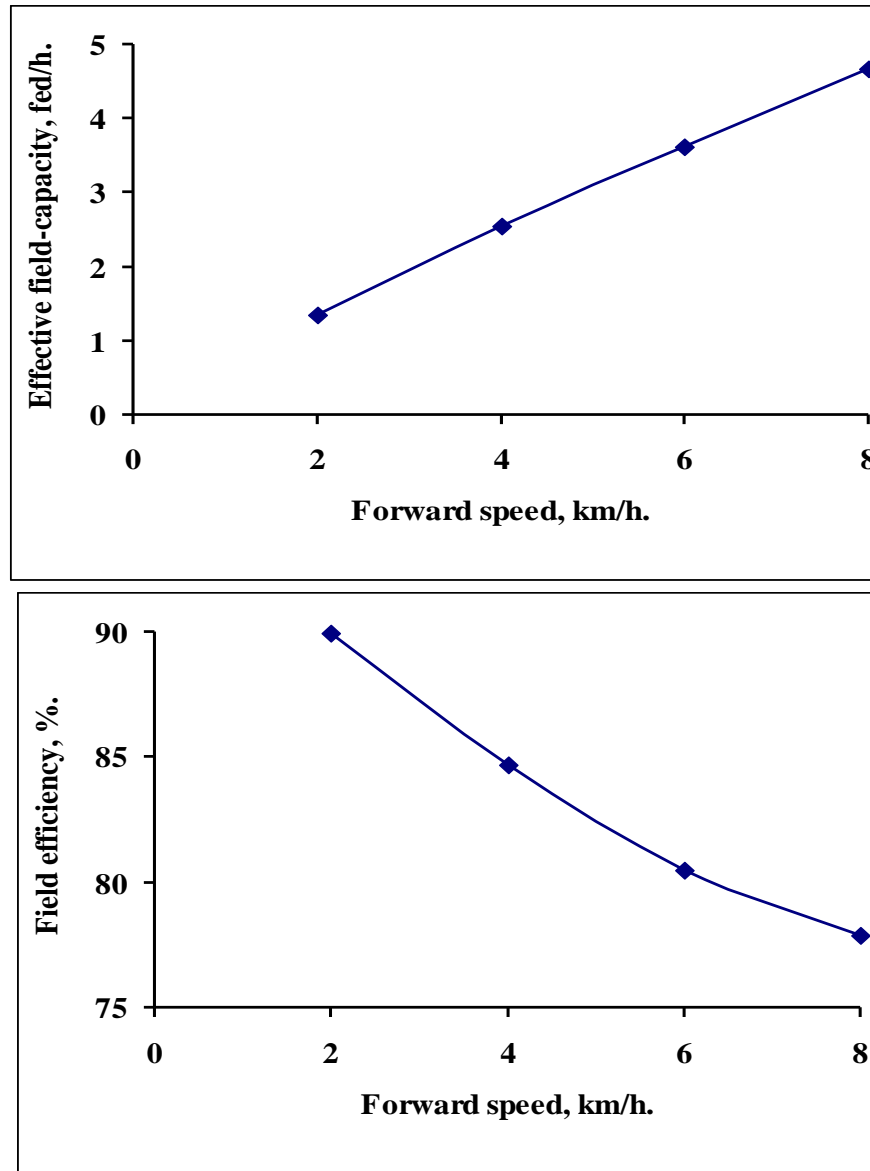

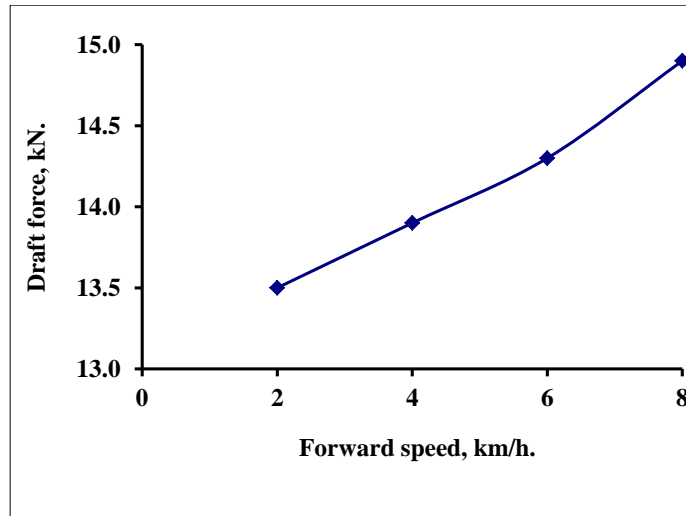**Fig. 12:-** Effect of forward speed on effective field-capacity and field efficiency.

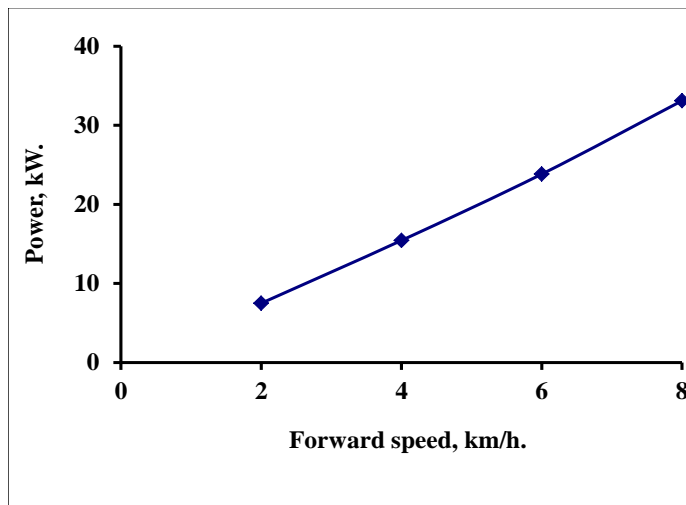**Fig. 13:-** Effect of forward speed on draft force.

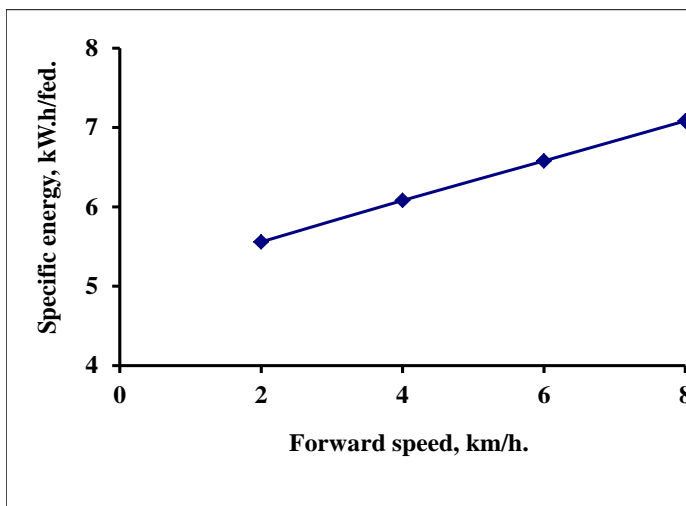**Fig. 14:-** Effect of forward speed on power.

Fig. 15:- Effect of forward speed on specificenergy.

Effect of forward speed on operation cost of grain-drill before and after metering-device development.
The operation cost decreased by increasingforward speed.The minimum planting-costs were 200 L.E./fed (according to the rent price of Agricultural Mechanization Sector at year of 2020). and57.72 L.E./ton were obtained using developed grain metering-device (drilling in hills) and forward speed of 8 km/h. Meanwhile, The maximum planting-cost was71.3 L.E./ton was obtained using grain metering-device before modification (normal drilling) and forward speed of 2 km/h. The cost by manual drilling in hills was 600 L.E./fed.

Conclusion:-
It was concluded that using the developed grain metering-device for drilling wheat in hills at optimum conditions: cell size of 7-8 grain/hill and forward speed of 2 km/h. The obtained results at optimum conditions were: plant emergence of 95.8 %, average hill-spacing of 11 cm, average grain/hill of 7, ground-wheel slip of 3.13 %, draft force of 13.5kN, powe of 7.5 kW, specific energy of 5.56kW.h/fed, field capacity of 1.35 fed/h, operation cost of 200 L.E/fed, and production cost of 57.72 L.E./fed.

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