DEVELOPMENT OF A DRUM SEEDING METERING UNIT FOR SOWING VEGETABLE PLUG TRAY SEEDLINGS

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Abstract

Manual indenting and sowing of small vegetable seeds in plug trays is a slow and labor-intensive operation, which limits the production capacities of vegetable nurseries in Egypt. High-capacity imported seeders have not been adopted by nursery growers due to their high costs. The objective of this study was to develop a precision a pneumatic drum seeding metering unit, using indigenous materials and off-the-shelf available standard components. Based on the design parameters obtained in laboratory experiments, a prototype pneumatic seeder was fabricated and tested for its performance for sowing cucumber and tomato seeds in plug trays. The seeder could make indents in one row of cells in a plug tray and simultaneously place single seeds in the indented cells. The seeder worked satisfactorily at suction pressures of 6 and 1.5 kPa and nozzle diameters of 1 and 0.8mm to achieve 90.48 and 80.86% single seed sowing in the case of cucumber and tomato, respectively. The capacity of seeder, depending on the tray size used 40320 and 100320 cells h_1 for cucumber and tomato seeds respectively. The total cost of sowing tray using a prototype precision plug seeder was found to be 0.09 LE/ tray against (0.67 and 1.67) LE/try for hand seeding for (cucumber tray and tomato tray) respectively.
Keywords: Plug tray, precision plug seeder

Introduction

In Egypt, vegetables are one of the important cultivated crops. Vegetable consumption in Egypt is one of the highest in the world it is more than 185 kg/year per capita Zaki (1992). Central Agency for Public Mobilization and Statistics (2018) mentioned that on 2016, the cultivated area of the cucumber was reached to 52087 feddan (1 feddan = 0.420 hectares) with production of 484 thousand ton. Sriwongras and Dostal (2013) mentioned that seeding seeds directly in the soil affects pre-germination of seed. The seed sown in plug tray by human hand have to spend a lot of time. Sowing machines for seedling production are expensive and sophisticated in working operation and complicated in maintenance.

Vavrina and Summerhill (1992) explained that a major portion of the area under vegetable cultivation is now sown with first generation hybrid seeds. Increasing the demand of vegetable seedlings encouraged nursery growers to use plug trays. Plug trays made from polystyrene and compressed foam are very common around the world. EL-Ghobashy *et al.* (2016) mentioned that in Egypt, the compressed foam plug trays are widely used, the common dimensions of the all foam plug trays types used commonly are (673×393×60) mm. Gaikwad and Sirohi (2008) studied the ergonomics conditions effect on manual plug tray sowing. They found that this operation makes worker with severe pains effects such as back ache, pains in fingers and arm. Naik and Thakur (2017) explained that the required time for sowing the manual tray saw is more than two minutes per tray for experienced worker. Tawfik (2014) pointed out the steps of the working of handy vacuum bulb plug tray seeding machine. Naik and Thakur (2017) developed a machine for single seeder. It was a simple and frugal design.

Morin (1995) used a wand with a plurality of ports is provided with vacuum and vibration and with controls in the process of sowing the plug trays. Fine and McKearney (1973) explained a work of device for planting seeds in an orderly array which has a plurality of suction needles adapted to be positioned over a seed-carrying tray. McDonald (2005) mentioned that the needle seeders function by establishing a vacuum through the row of needle tips. The needle tips are placed into the seed tray, where each tip picks up a seed. The tips containing the seeds are raised from the seed tray, lowered over a wide mouth drop tube, the vacuum turned off, and seeds released where they slide down the individual drop tubes for accurate placement in the plug cell. Mohamed *et al.* (2017) designed a bulk seeding unit for planting the plug tray with the same dimensions and holes in plug tray. EL-Ghobashy *et al.* (2016) developed a precision vacuum trays bulk seeder and tested it for seeding single seed in the trays (84 and 209 cells) for cucumber and cabbage seeds under four different suction pressure and four different hole size diameters. Singh *et al.* (2005) mentioned that to prevent the seed from entering the seed hole, angle of edges openings on the seed plate should be conical in shape to be completely closed by a seed to avoid multiple seeds being picked up by the seed plate. Bakhtiari (2012) and Singh *et al.* (2005) mentioned the most suitable conical angle of the seed plate is 120°. McDonald (2005) mentioned that the needles are usually made of steel, although rubber tips are available for singulation of flower crop seeds with rough surfaces. Tawfik (2014) mentioned that the funnels can be used to dispense seeds from the seed box in plug tray cells accurately. They experimented index seeder to plug tray. The mechanism is powered by compressed air and controlled by a Programmable Logic Controller (PLC). Grianggai and Kiattisak (2014) used PLC for control a seeder model. The Seeder and Coverer are controlled by a Microprocessor PLC to synchronize the tray with the Seeder. McDonald (2005) mentioned that the Drum seeders are primarily used in automated, high-volume seeding operations. Kim *et al.* (2003) reported that the important operating factors for

obtaining high seeding rates were typically nozzle diameter and vacuum pressure. Rathinakumari *et al.* (2005) developed a tray vacuum seeder for small vegetable nursery growers. A suction pressure of 49.03 kPa with hole of 0.5 mm diameter were reported to be sufficient for single-seed. Karayel *et al.* (2004) identified the optimum vacuum pressure of a precision vacuum seeder by using some physical properties of seeds such as one thousand seeds mass, projected area, sphericity and seed thickness. Guarella *et al.* (1996) mentioned that the performance of a vacuum seeder depends on the maximum distance at which seeds may be picked up from the nozzle, the dimensions of the nozzle and on the shape and dimensions of the seeds. Gaikwad *et al.* (2007) conducted studies to determine optimum suction pressure and nozzle size for the singulated picking of tomato and capsicum seeds in the case of capsicum was 4.91 kPa and 0.49 mm and for tomato it was 3.92 kPa and 0.46 mm, respectively. Tawfik (2014) designed and tested a prototype for seeding tomatoes seeds in tray. The results indicated that the best value of feeding device height that fulfill catching one seed per orifice was h =2.2 mm at suction tube orifice diameter of 0.5mm and air suction pressure of 3.34kPa. Abdolahzare and Mehdizadeh (2014) stated that seed is an important criterion in evaluating seeder performance. Zigmanov (1997) concluded that the factors affecting the efficiency of sowing were the degree of vacuum, nozzle diameter, the shape of the seed as well as the degree of seed finishing. Barut (1996) mentioned that the various physical properties of seeds are the most important factors in determining the optimum vacuum pressure of the vacuum seeder.

The experiments indicated the economical effect of using mechanical tray seeder. Naik and Thakur (2017) mentioned that the automation in the seeder will help in reducing the wastage of the costly seeds, time required for sowing and minimizing the workers expenses. Gaikwad and Sirohi (2008) stated that the cost of sowing plug trays with a precision plug seeder was calculated and compared with the cost of manual seeding of the same trays. The total cost of sowing 1000 cells with a precision plug seeder was only 15.27% of the cost of manual sowing. Mohamed *et al.* (2017) calculated the operating costs included fixed and variable costs for a wagon bulk tray seeding machine. The total operating costs for the seeding machine was 2.7 $/h.

Seeding metering unit is the heart of the plug trays seeding machine.

The main idea of this research is designing and manufacturing a precision seeding metering unit suitable with the common vegetables seeds.

Materials and Methods

The seeding metering unit was designed and manufactured in the Agricultural Engineering Research Institute (AEnRI) workshop – Ministry of Agriculture - Egypt. It was depended on the negative pressure pass through a rotating cylindrical drum. The drum was equipped with small holes with a diameter suitable for one seed dimensions. The drum was designed to sow one by one tray per each its complete revolution. The seeding metering unit was constructed of three sub-units as the following:

(I) Seeding drum metering sub-unit.   (II) Pneumatic sub-unit. (III) Transmission sub-unit.

I) Seeding drum metering sub unit:

The seeding drum metering sub unit consisted of:

a) Metering unit frame:

The frame was made of square hollow aluminum section (40 mm ×40 mm ×2 mm thickness). The total dimension of the frame was 600 mm length, 380 mm width and 300 mm height. The parts were fit to each other by three directions right angle plastic fitting. These dimensions were selected to allow the trays pass underneath the frame with its width to decrease the number of sowing holes on the drum per each tray row.

b) Sowing drum:

A drum with 84 holes was manufactured to suit the type of the sawed cucumber seeds. A cylindrical shape drum body was made for PVC with diameter of 200 mm, length of 391 mm, and thickness of 5mm. Two bases sides were made of Teflon and lathed to tit on each side of the drum. Two steel flanges with diameter of 155 mm were fitted on each cover side by bolts and nuts. Two shafts made of stainless-steel pipe (SS 304) were welded to the side drum flange to transmit the motion to the drum and transfer the negative vacuum to the drum from each side. The shaft outer diameter was 35 mm and inner diameter was 30 mm. Each shaft was rotating on (UCP207) bearing housing fitted on the frame by two bolts and nuts. A sprocket was fitted on the shaft to transmit the motion to the drum.

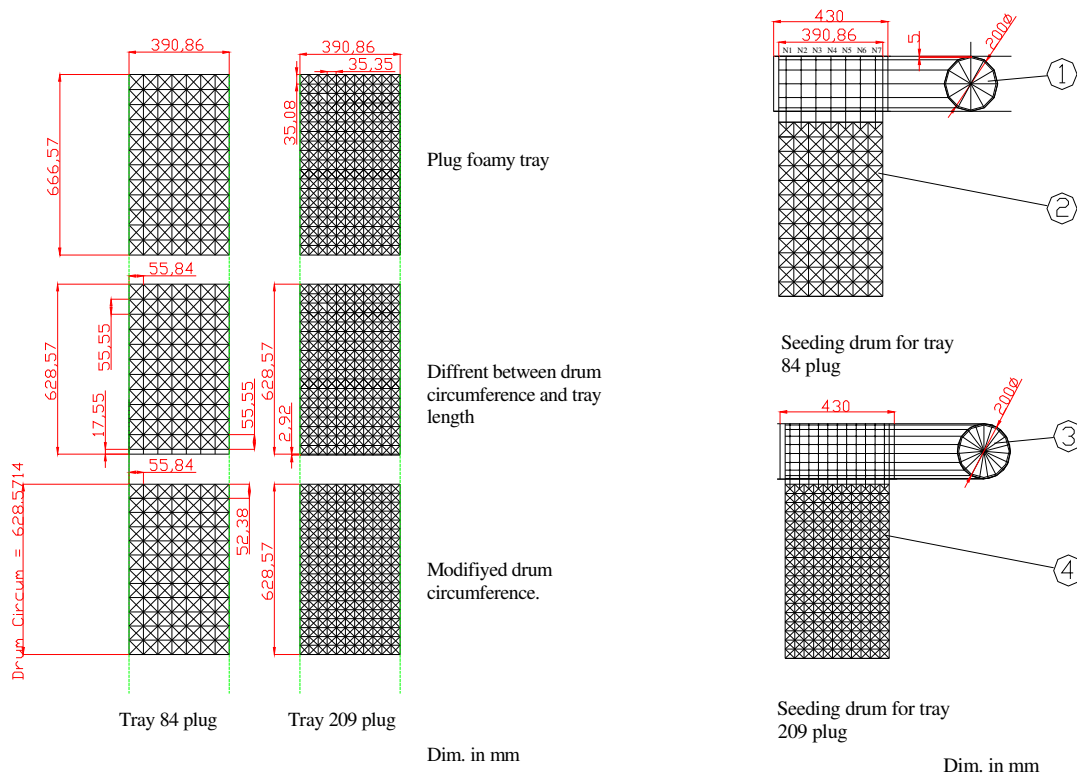### Determination of sowing drum diameter

A comparison between tray length and expected drums circumference was made to choose the suitable sowing drum diameter. The selected drum diameter was chosen from the commercial sizes available in the local market.

The trays dimensions were surveyed to find out the average tray length and width. The average tray length ($\overline{L}_t$) was 666.57 mm, and the average tray width ($\overline{W}_t$) was 390.86 mm.

The nearest available pipe diameter size is 200 mm that nearly match the trays length. The drum circumference

$$(L_d) = \pi \, d = \pi \times 200 = 628.57 \text{ mm}$$

There were differences between tray average length and the drum circumference by 17.55 mm, and 2.92 mm with 84 plug trays and 209 plug trays respectively. The drum was redesigned to locate the right positions of the holes to match the center positions of the plug cells to ensure each seed is located in the center of plug cell.

a) The difference between the sowing drum circumference and the average trays length

b) The designed sowing drum holes positions

Fig. 1: Determination of sowing drum diameter
(1) Seeding drum for tray 84 plug (2) Tray 84 plug (3) Seeding drum for tray 209 plug (4) Tray 209 plug

c) Skimmer:

A rectangular shape skimmer was used to skim the seeds from the sowing cylinder holes to drop them into the plug tray cells. The skimmer was toughed the drum circumference with an angle of 25°along the drum cylinder height.

d) Cleaning brush:

Cleaning brush was used to clean any impurities, dust, and seed residue adhering to the holes. It was fitted before the drum seeds catching zone.

e) Seed hopper:

The Seed hopper was made from plastic sheets. It was designed to allow the seeding drum rotate freely without touching it and prevent the fine seeds leakage. The drum box was equipped with articulated lower door to drop the remained seeds in the box after seeding. The door was locked with two tensioned springs hanged from each door sides.

The repose angle for some common vegetables seeds was measured. It was 30° for cucumber. The seed hopper bottom was a prism shape with an angle of 15° that less than common seed repose angles. This design ensured the seeds slid in picking area and prevent their stop in the bottom of the seed hopper.

f) Seed hopper vibrator:

An electrical motor (220 V, 3000 rpm) was fixed underneath the bottom of the seed box. An eccentric weight was fixed to the motors shaft to generate the vibration motion. The vibration increased the seeds chance to meet the drum holes.

g) Seed selectors:

Both 84 and 209 trays seed positions were defined and located on the seeding drum. Fig (2) shows the locations of 84 and 209 holes on the circumference of the seeding drum.

Two seed selectors were designed for 84 and 209 plugs trays. The seeding drum was drilled with 84 and 209 holes in the same time on its circumference. When using 84 holes selector, all holes in the drum begin to catch the seeds. The 84 holes selector placed in a position to remove the seeds catches with the holes of 209 holes and only allows the seeds catched with the holes of 84 tray to pass between the selector fingers. The distance between fingers was determined according to the maximum dimensional properties mentioned in Table (2). The selector was placed in a position above the seed hopper to allow the removed seeds to return back to the seed hopper.

The results of the design experiments indicated that all the holes of 84 and 209 on the seeding drum never come on the same line when the seeding drum is moving to sow the seeds except the middle line. For preventing double seeding, the center holes on the drum of 209 trays were shifted by 5 mm horizontally.

When using 209 holes selector the seeds in the middle were not in the right position to drop into the middle plug of 209 tray and shifted by 5 mm. A corrector finger was fitted in the middle of the skimmer by 5 mm was used to return the seeds to their right position. The innovated selectors decreased the required time for changing the drum and increase the productivity of the machine.
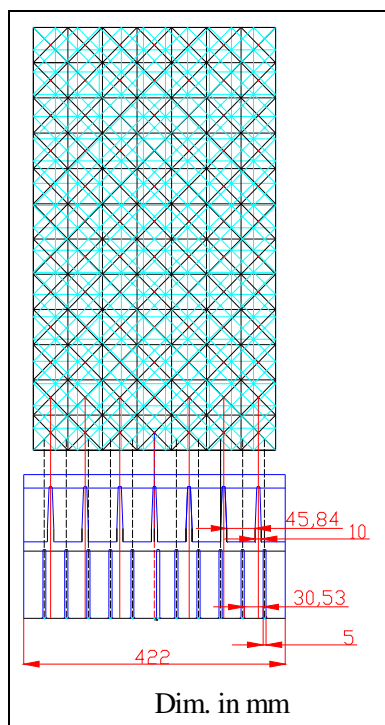
Fig. 2 : Design of the 84 and 209 trays selectors

Determination of the drum holes diameter for seeding unit:

Some physical properties for cucumber and tomato seeds were measured to assess the holes diameter. The physical properties were, seed length (L_s); mm, seed width (W_s), mm, seed thickness (T_s); mm, mass of 1000 seeds (K_m); g, volume (V); mm³, percentage of sphericity (S); %, geometric diameter (D_g); mm, arithmetic diameter (A_d) ;mm, Also the standard deviation (SD) and coefficient of variance (CV) was calculated from the results for each measurement. The digital vernier caliper was used to measure seeds principal dimensions, seed length (L_s), width (W_s) and thickness (T_s). Samples of 100 seeds were randomly selected and the principal dimensions were measured (accuracy of 0.01 mm).

Singh *et al.* (2005) mentioned that the seed geometric mean diameter (D_g) can be calculated by the following formula:

$$D_g = \left(L_s \times W_s \times T_s\right)^{1/3} \qquad ...(1)$$

Also, Abalone *et al.* (2004) mentioned that the sphericity (φ) of the seeds is calculated by the following formula: -

$$\varphi = \frac{D_g}{L_s} = \frac{\left(L \times W \times T\right)^{1/3}_s}{L_s} \qquad ...(2)$$

According to (Singh *et al.*, 2005) considered the opening diameter (do) based on the less than or equal 50% size of the geometric mean diameter ($d_o \leq 50\%$ D_g). Due to this study, the geometric mean diameters of seeds are D_g = 3.67 mm for cucumber and 1.45 mm for tomato, Thus:

$d_o \leq 0.50 \times 3.67$ mm. Then $d_o \leq 1.84$ mm for cucumber.

$d_o \leq 0.50 \times 1.45$ mm. Then $d_o \leq 0.73$ mm for tomato.

II) Pneumatic sub unit

A negative pressure was used to catch the seeds into the seeding holes.

A vacuum blower (220V, 2500rpm) was used to generate a negative pressure flowed to the seeding drum via a group of pipes and fitting. A main air inlet valve was used to control the negative pressure.

a) Mechanical pneumatic adaptor:

A mechanical pneumatic adaptor was designed and manufactured to move the drum rotating shaft and allow the negative pressure inside the shaft in the same time.

b) Pressure distribution on the drum holes:

The drum shafts were manufactured of stainless-steel pipes (SS 304). Experiments were made to find out the effect of negative pressure on the drum holes from one side and two sides.

One negative pressure inlet:

The negative pressure was measured on the inlet of the mechanical pneumatic adaptor on -6, -8, -10, -12 and, -14kPa. After fitting the mechanical pneumatic adaptor in the 84 holes drum outlet, the pressure was measured in all holes of the drum row by row.

Fig. (3) shows the distribution of pressures on the holes when using one inlet negative pressure. From Fig. (3), it realized that the average pressure is not regular on the holes on low pressures -6, -8 and -10 kPa. When increasing the pressure to -12 and -14 kPa the pressure at the holes starts to be regular.
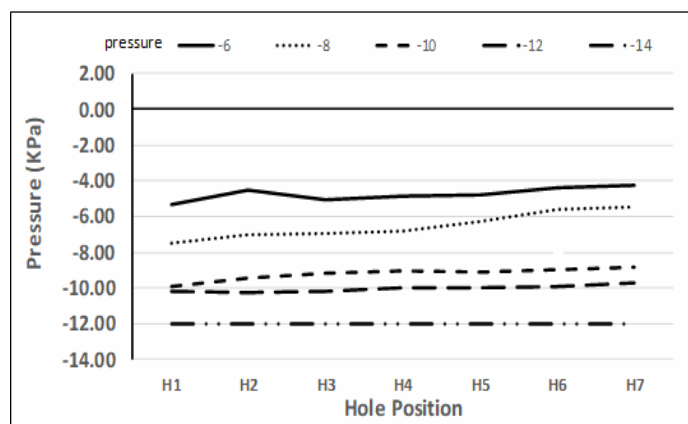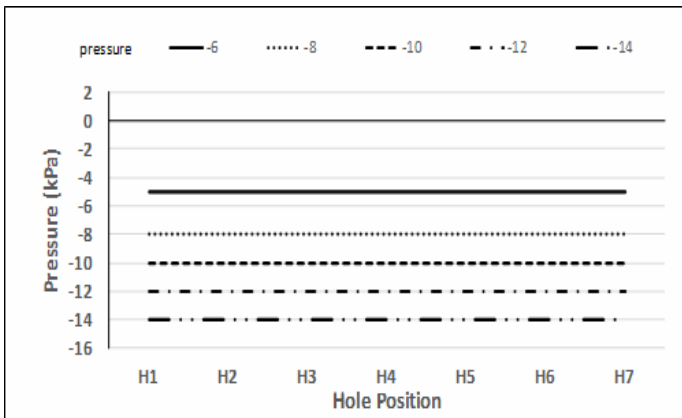

Fig. 3: Pressure distribution on holes for one negative pressure inlet

Two negative pressure inlets:

Two mechanical pneumatic adaptors were fitted on the two outlets of the same drum. Negative pressure was measured on the inlet of the mechanical pneumatic adaptor on -6, -8, -10, -12 and, -14kPa. Then, the pressure was measured in all holes of the drum row by row.

Fig. (4) shows the distribution of pressures on the holes when using two inlets for negative pressure. From Fig. (4), it realized that the average pressure is regular on the holes at all inlet pressure from -6 and -14 kPa the presser at the holes begin to be regular.

Fig. 4 : Pressure distribution on holes for two negative pressure inlets

From Fig. (3), and Fig. (4), it is realized that the two inlets suitable for stable negative pressure along the drum length.

(III) Transmission and power source sub-unit:
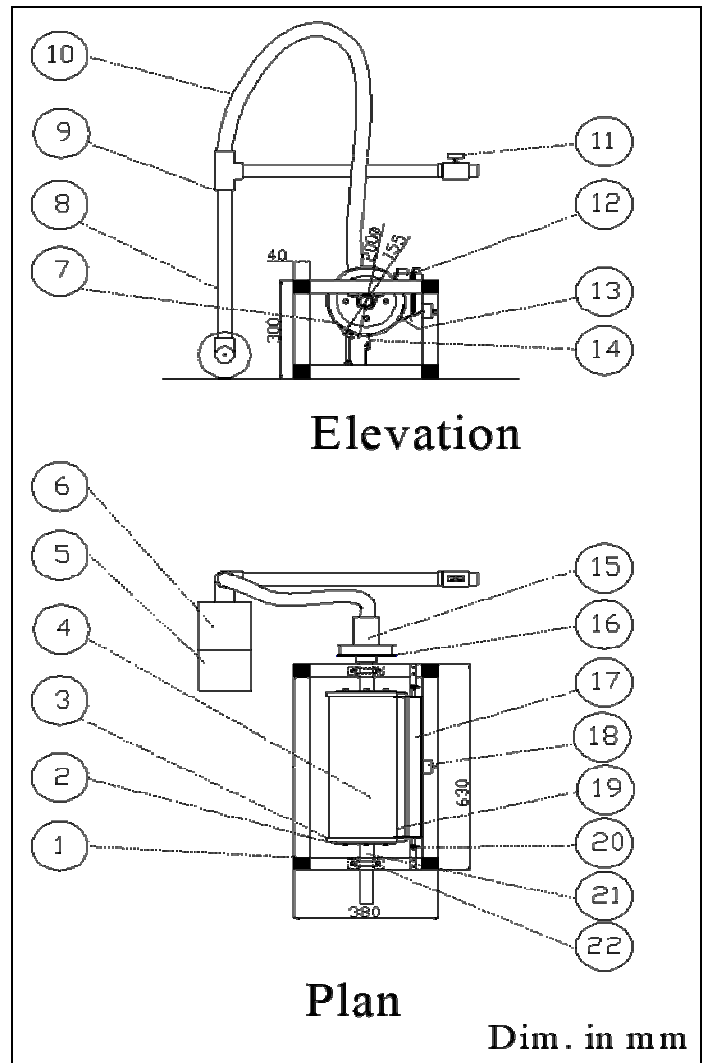
a) Frame

The Transmission frame was made from square hallows steel sections of (50 mm ×50 mm ×1 mm thickness). The parts were fit to each other by welding. The dimension of the frame was (1500 mm length, 630 mm width and 80 mm height).

b) Transmission

The transmission sub unit was consisted of driving pulley fitted on the electrical motor and transmitted the motion to a driven pulley by double V type belt. The driven pulley was fitted on gear box shaft with reduction ratio of 1:35. The gear box drive shaft was transmitting the motion perpendicularly to a driven shaft equipped 6 cm diameter pulley. The drive pulley transmitted the motion to 13.2 cm diameter pulley fixed on the seeding drum shaft via flat belt 3 cm width. The motion changed by changing the pulleys diameter fixed on the motor and the gear box.

c) Power source:

A single-phase electrical motor (220V), one hp, 1400 rpm, and 24 mm shaft diameter was fitted to the machine as a source of power. Fig. (5) shows a schematic diagram of the plug tray seeder metering unit.

Fig. 5 : A schematic diagram of the plug tray seeder metering unit.

(1) Metering unit frame; (2) Drum side flange; (3) Drum side cover; (4) Drum body; (5) Vacuum motor; (6) Vacuum blower; (7) Seed skimmer; (8) Vertical vacuum pipe; (9) T-PVC fitting; (10) Flexible plastic pipe; (11) Vacuum adjustable tap; (12) Seed hopper door spring; (13) Seed hopper door; (14) Cleaning Brush; (15) Mechanical pneumatic adaptor; (16) Drum transmission pulley; (17) Seed hopper; (18) Seed Hopper vibrator; (19) Seed selector; (20) Door lock; (21) Spacer; (22) Drum bearing housing.

Fig. 6 : An Image of the seeding metering unit

Testing procedure:

The machine was tested on cucumber seeds as a sample of large seeds and tested on tomato seeds as a sample of fine seeds. The tomato seeds (variety of Super-Marmande), and

Cucumber seeds (Ghazeer variety) were used in experiments. Both varieties were treated with anti-fungi that gave them a notice color could be observed during treatments. The germination ratio was measured on both varieties in Petri

plates. The machine planted the tomato seeds in 209 cell trays meanwhile the cucumber seeds were planted in 84 cell trays after changing the nozzles holder. After any treatment the trays were nursed and germination was measured to find the effect of the machine on seeds germinates.

Negative pressure gauge (manometer): (from 0 to -100 millibar) (accuracy of 1 mille bar) to measure the negative pressure on the holes. (10 millibar =1kPa). Camera and laptop computer: to record the seeding efficiency on the seeding drum in each drum rotation

Experimental treatments:

The following treatments were studied to evaluate the main design operating parameters affecting on the performance of the developed machine as shown in table (1).

Table 1 : Experimental plan for evaluating the machine.

Variables	Levels
Hole size diameters, mm	076, 1, 1.2, 1.4 with cucumber 0.4, 0.6, 0.8, 1.0 with tomato
Negative pressure, kPa	6, 8, 10 and 12 with cucumber 1, 1.5, 2 and 2.5 with tomato
Drum speed, m s^{-1}	0.06 ,0.08, 0.1 and 0.12

Results and Discussion

1. Dimensional characteristics of cucumber and tomato seeds:

Table 2 : Physical properties of cucumber and tomato seeds

Seeds type	Cucumber (Ghazeer variety)						Tomato (Super-Marmande variety)					
Properties	Maximum	Average	Maximum frequency	Minimum frequency	SD	CV	Maximum	Average	Maximum frequency	Minimum frequency	SD	CV
Seed length, L_s, (mm)	10.09	8.94	9-9.99	$\geq$10	0.62	6.90	3.17	2.63	2.25– 2.49	1.75–1.99	0.26	9.73
Seed width, W_s, (mm)	4.27	4.12	4-4.49	3–3.49	0.25	6.18	1.75	1.83	1.75– 1.99	1– 1.24	0.18	9.95
Seed thickness, T_s, (mm)	1.16	1.40	1.30–1.59	<1	0.23	16.19	0.6	0.64	0.6– 0.69	$\geq$1.1	0.09	14.36
Geometric diameter, D_g, (mm)		3.70			0.25	6.85		1.45			0.12	7.98
Arithmetic diameter (mm)		4.82			0.26	5.47		1.70			0.13	7.86
Sphericity, φ, (%)		41.52			2.59	6.23		55.48			4.32	7.79
Seed volume (mm^3)		26.98			5.37	19.92		1.63			0.41	25.34
Transverse surface area (mm^2)		4.51			0.78	17.33		0.93			0.20	21.10
Flat surface area (mm^2)		28.91			2.93	10.14		3.80			0.62	16.20
One seed thousand weight, (M_g)		0.0000285						0.000002				
Repose angle, (degree)		25						30				

SD: Standard division   CV: Coefficient of variation

To prevent the seed from entering the seed hole, angle of edges openings on the nozzle should be conical shape to avoid multiple seeds picked up by the hole Singh *et al.*, 2005. According to Bakhtiari, 2012 and Singh *et al.*, 2005, the most suitable conical angle of the hole is 120°. Fig. (7) shows the conical angle of the hole.


Fig. 7 : The conical angle of the hole (120°).

2. The effect of seed hopper vibrator on seeding efficiency:

The experiments were carried out to sow cucumber seeds with 84 sowing drum selector, at five negative pressures to study the effect of the vibrator on seeding efficiency. The experiments were done with (1.00 mm) hole diameter at five negative pressure (-6, -8, -10, -12, and -14) kPa.

Fig. (8) shows the effect of the seed hopper vibrator on seeding efficiency at different negative pressure with cucumber seeds.
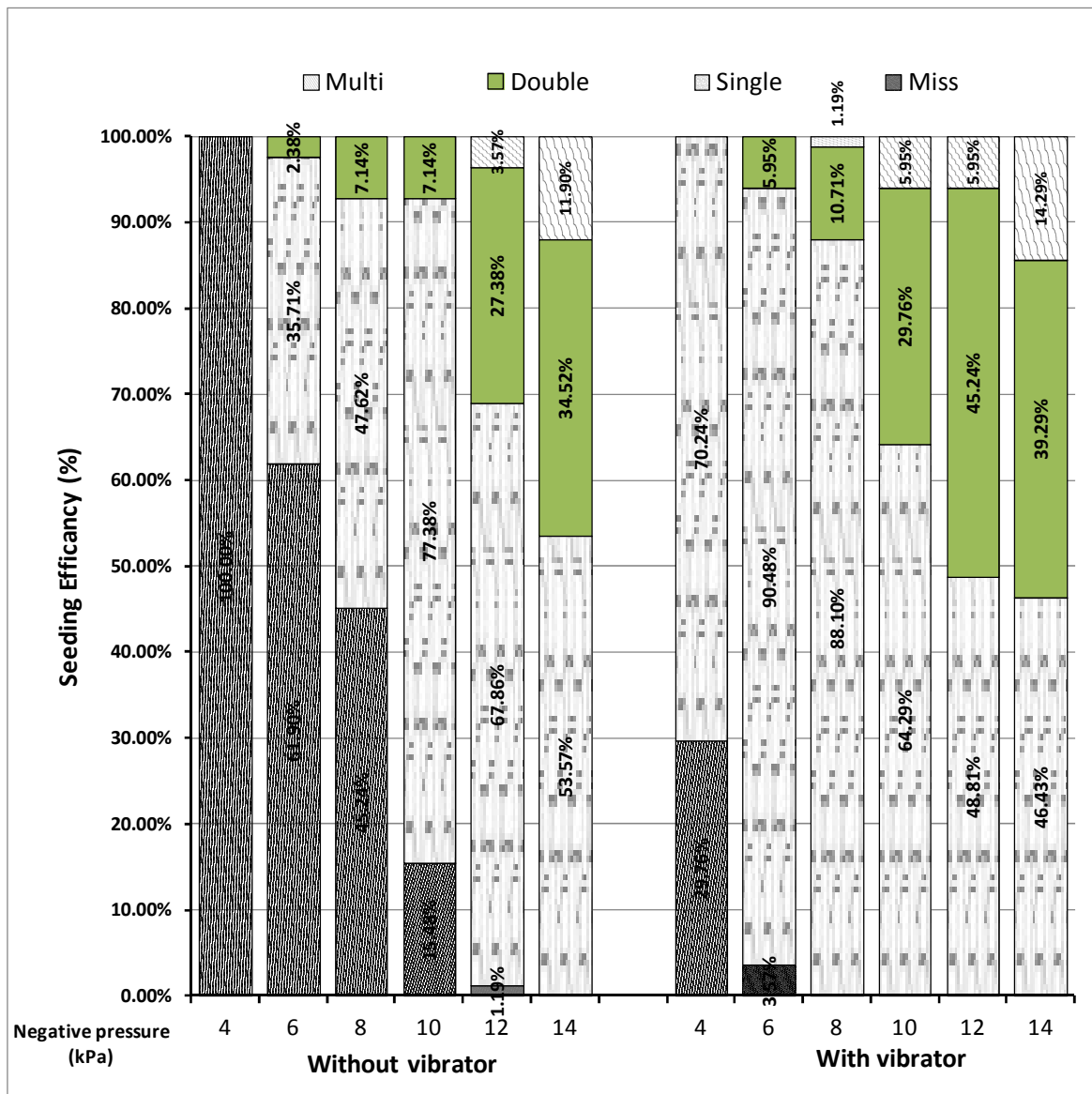
Fig. 8 : The effect of the seed hopper vibrator on seeding efficiency at different negative pressure with cucumber seeds.

Without using seed hopper vibrator, the maximum seed singulation percentage was 77.38% at negative pressure of -10kPa. Meanwhile, by using the vibrator the maximum seed singulation percentage was 90.48% at negative pressure of -6kPa Also, without using seed hopper vibrator the minimum seed singulation percentage was 35.71% at negative pressure of -6kPa. Meanwhile, without using the vibrator the minimum seed singulation percentage was 46.43% at negative pressure -14kPa.

By using the vibrator, the missed holes percentage at negative pressure at negative pressure (-4, -6, -8, -10, -12, -14kPa) decreased by (70.33, 94.23, 100, 100, 100, 100%) respectively. By using the vibrator, the double holes percentage at negative pressure (-4, -6, -8, -10, -12, -14kPa) increased by (0, 60, 33.33, 76, 39.47, 12.12%) respectively. By using the vibrator, the multiple holes percentage at negative pressure (-4, -6, -8, -10, -12, -14kPa) increased by (0, 0, 1.19, 5.95, 40, 16.72%) respectively.

By using the vibrator, the single holes percentage at negative pressure (-4, -6, -8kPa) increased by (70.24, 60.53, 40.95%) respectively and at negative pressure (-10, -12, -14kPa) decreased by (16.92, 28.07, 13.33%) respectively.

Therefore, it is recommended to use the vibrator in all experiments.

3. The effect of hole diameter and negative pressure on seeding efficiency of cucumber seeds: -

The experiments were carried out to plant cucumber seeds in 84 cell plug trays to study effect the hole diameter and negative pressure on seeding efficiency. The average values of seeding efficiency (%) were monitored with holes diameter of (0.76, 1.00, 1.20 and 1.40 mm) by increasing hole diameter by drill and changing the negative pressure from (6.0 kPa) to (8.0, 10.0 and 12.0 kPa) by adjusting the air inlet valve. The treatments were done to determine the optimum calibration of the negative pressure and the optimum hole diameter. Fig. (9) shows the effect of hole diameter and negative pressure on seeding efficiency of the cucumber seeds.

From Fig. (9), it was realized that maximum seed singulation ratio was 90.48% at hole diameter of 1.00mm and negative pressure 6.0 kPa.

Meanwhile, the minimum seed singulation ratio was 34.52% at hole diameter of 1.40 mm and negative pressure 12.00 kPa. By increasing the hole diameter from 0.76 to 1.00 mm the average singulation decreased from 74.70 to 72.92 %. Meanwhile by increasing the hole diameter from 0.76mm to (1.20 and 1.40mm) the average singulation percentage decrease from 74.70% to (67.26 and 54.46%) respectively.
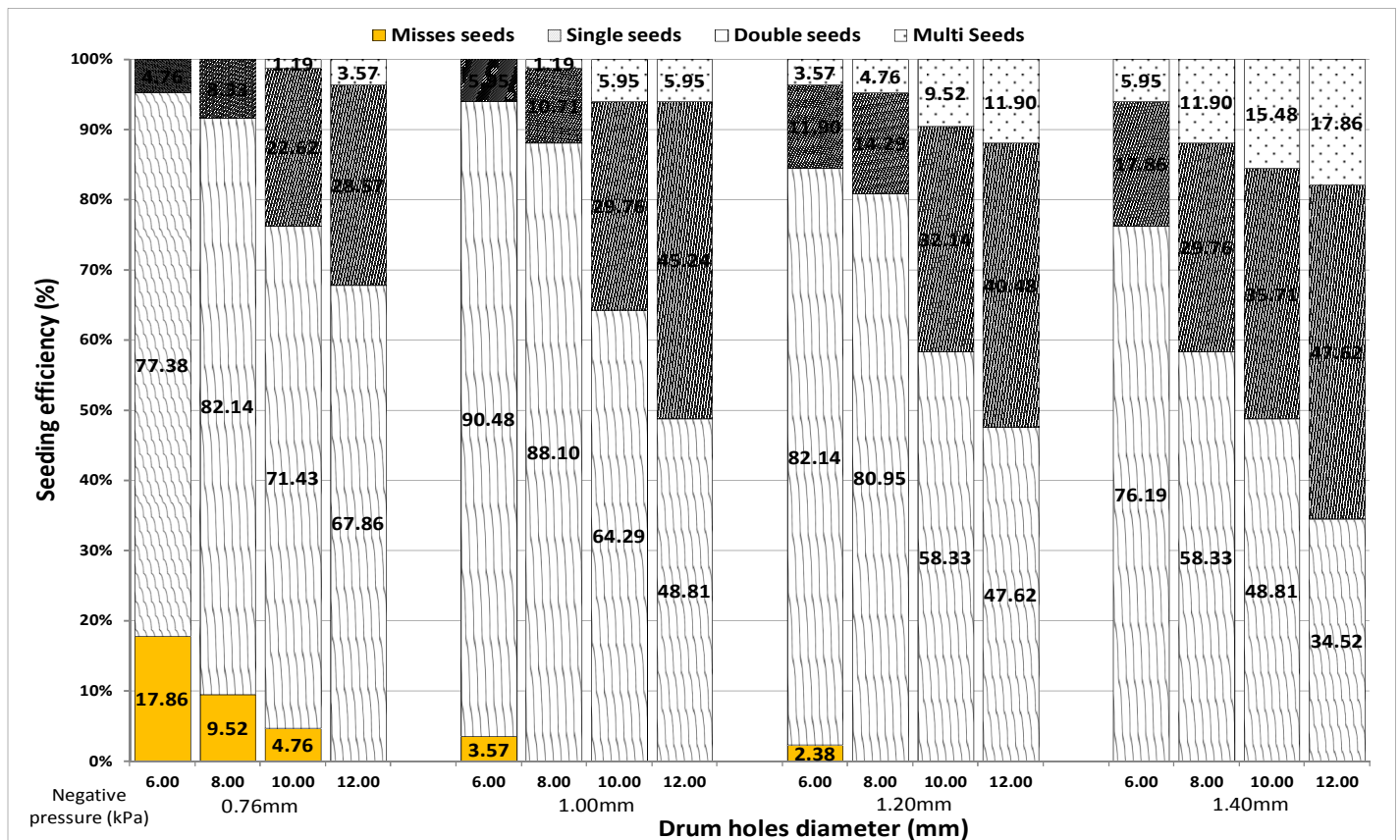
Fig. 9 : The effect of Drum holes diameter and negative pressure on seeding efficiency of cucumber seeds

At hole diameter 0.76 mm, the seed singulation ratio increased from 77.38% with increasing percentage of 5.8% when increasing the negative pressure from 6.0 kPa to 8.0 kPa. By increasing the pressure from 6.00 kPa to (10.00 kPa and 12.00 kPa) the seed sigulation ratio decreased by 8.33% and 14.04% respectively.

The relation takes the same trend at hole diameter of 1.00mm with decreasing percentages of (2.70, 40.47, 85.37%) when increasing the negative pressure from 6.0 kPa to (8.0, 10.0, and 12.0 kPa) respectively.

At negative pressure of 6.0 kPa, hole diameter of 1.2 and 1.4 mm the single seed percentage was decreased by (1.47% and 30.61%), (40.82% and 56.10%) and (72.5 and 120.69%) respectively when increasing the negative pressure from 6.0 kPa to (8.0 and 10 kPa).

Also, it was found that the double seed average percentage was increasing by increasing the hole diameter. The average percentage was increased from 16.07 to 22.92, 24.70 and 32.74 when increasing the hole diameter from 0.76mm to (1.00, 1.20, and 1.40 mm) respectively. The relation was taken the same trend with multi seed average percentage with increasing ratio from 1.19% to (3.27, 7.44 and 12.80) respectively.

From Fig. (9), it was realized that the optimum hole diameter for planting the cucumber seeds is 1.00 mm operated at negative pressure 6.0 kPa that gave percentage of

single seed 90.48 %, double seeds 3.57%, multiple seeds 0.00% and missed seeds 3.57%. Also, a random sample of the planted trays was nursed to find out the effect of the machine on seeds variability. The average plants emergence percentage was ($\approx$ 92%).
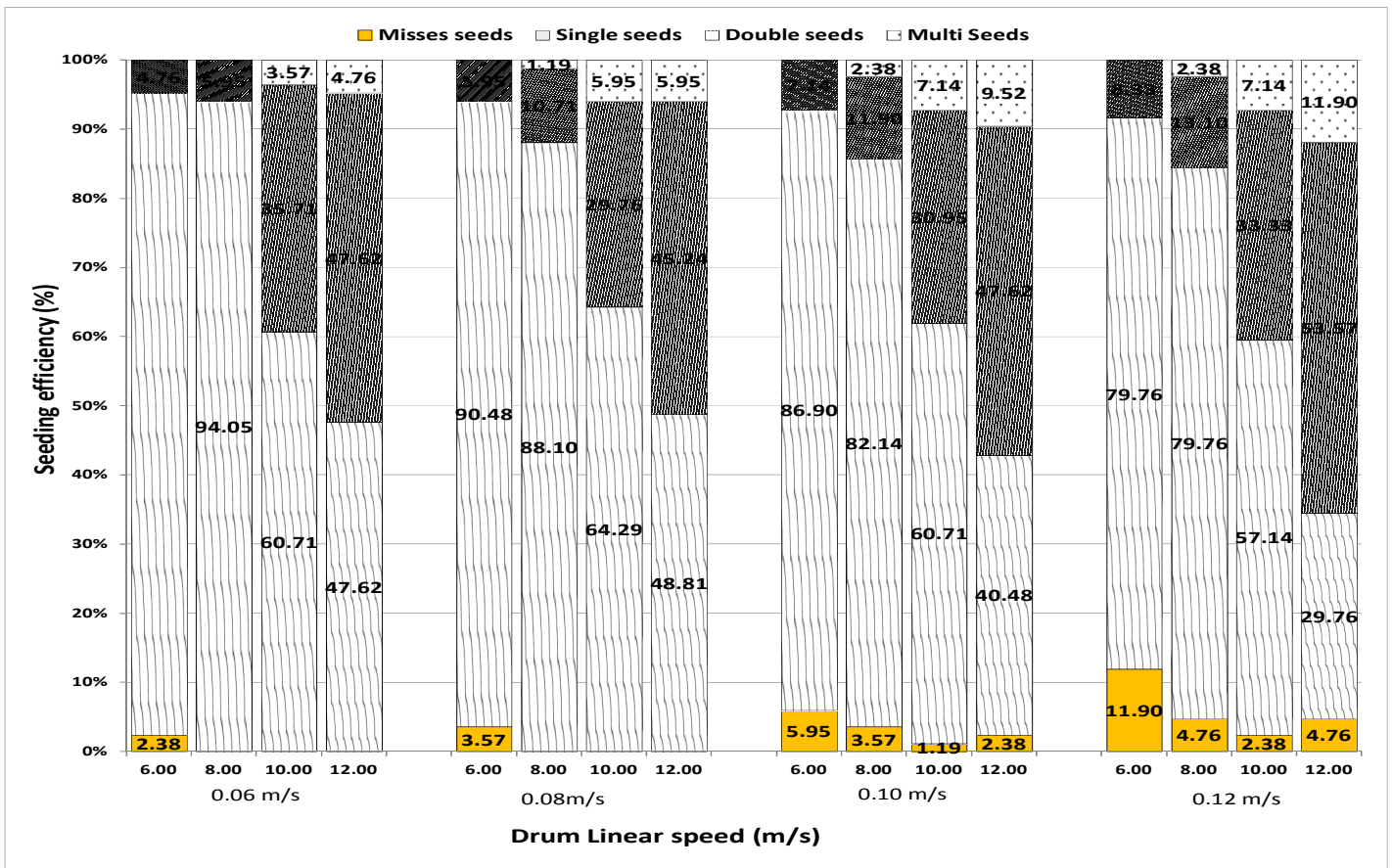
4. The effect of drum liner speed on seeding efficiency of cucumber seeds:

The experiments were carried out to sow cucumber seeds in 84 cells plug trays to study effect the drum linear speed and negative pressure on seeding efficiency with the optimum hole diameter 1 mm. The average values of seeding efficiency (%) were monitored with drum liner speed of (0.06, 0.08, 1.00 and 0.12 m/s) by changing the main motor pulley and changing the negative pressure from (6.0 kPa) to (8.0, 10.0 and 12.0 kPa) by adjusting the air inlet valve. The treatments were done to determine the optimum calibration of the negative pressure and the optimum drum linear speed. Fig. (10) shows the effect of drum linear speed and negative pressure on seeding efficiency of the cucumber seeds.

From Fig. (10), it was realized that maximum seed singulation ratio was 92.86% at linear speed 0.06 m/s and negative pressure 6.0 kPa.

Meanwhile, the minimum seed singulation ratio was 29.76% at linear speed 0.12 m/s and negative pressure 12.00 kPa.

Fig. 10 : The effect of drum liner speed on seeding efficiency of cucumber seeds

From Fig. (10), by increasing linear speed from (0.06 m/s to 0.08 m/s, 0.1 m/s, and 0.12 m/s) the average singulation decreased from 73.81 to (72.92 %, 67.56%, and 61.61%) respectively. Meanwhile by increasing the hole diameter from 0.76mm to (1.20 and 1.40mm) the average singulation percentage decrease from 74.70% to (67.26 and 54.46%) respectively.

Also, it was found that the double seed average percentage was increasing by increasing the linear speed. By increasing the drum linear speed from 0.06 m/s to (0.1 m/s, and 0.12 m/s) the average double seeds increased from 23.51 to 24.40 %, 27.08% respectively.

The relation takes the same trend with the multi seeds percentage. The multi-seed average percentage was increased from 2.08% to 3.27%, 4.46% and 5.36 by increasing the linear speed from 0.06 m/s to (0.08 m/s, 0.1 m/s and 0.12 m/s) respectively.

By calculation the total numbers of seeds excluded the single seeds, it realizes the minimum number was 88 seeds at drum linear speed 0.06 m/s and negative pressure 6.00 kPa with singularly of 92.86%. Then, it was 89 seeds with sigulaty of 90.48 at 0.08 m/s and negative pressure 6.00 kPa with difference of only one seed with the drum linear speed 0.06 m/s.

The linear drum speed which synchronized with the tray conveyor is surly will effect on the rate of performance of the machine.

This indicate that, the optimum drum linear speed is 0.08 m/s with negative pressure 6 kPa with hole diameter of 1 mm with 90.48% single seeds,5.95% double seeds ,3.57% missed seeds, and 0.00% multi seeds.

5. The effect of hole diameter and negative pressure on seeding efficiency of the tomato seeds:

The experiments were carried out to sow tomato seeds in 209 cell plug trays to study effect the hole diameter and negative pressure on seeding efficiency. The average values of seeding efficiency (%) were monitored with holes diameter of (0.40, 0.60, 0.80 and 1.00 mm) by increasing hole diameter by drill and changing the negative pressure from (1.0 kPa) to (1.5, 2.0 and 2.5 kPa) by adjusting the air inlet valve. The treatments were done to determine the optimum calibration of the negative pressure and the optimum hole diameter. Fig. (11) shows the effect of hole diameter and negative pressure on seeding efficiency of the cucumber seeds.

From Fig. (11), it was realized that maximum seed singulation ratio was 81.34% at hole diameter of 1.00mm and negative pressure 6.0 kPa.

Meanwhile, the minimum seed singulation ratio was 34.52% at hole diameter of 0.80 mm and negative pressure 2.0 kPa. By increasing the hole diameter from 0.40 mm to 0.60 and 0.80mm the average singulation increased from 71.77 to (73.56 % and 78.59%) respectively. Meanwhile by increasing the hole diameter from 0.40mm 1.00mm, the average singulation percentage decrease from 71.77% to 73.09%.

Meanwhile, the minimum seed singulation ratio was 34.52% at hole diameter of 0.80 mm and negative pressure 2.0 kPa. By increasing the hole diameter from 0.40 mm to 0.60 and 0.80mm the average singulation increased from 71.77 to (73.56 % and 78.59%) respectively. Meanwhile by increasing the hole diameter from 0.40mm 1.00mm, the average singulation percentage decrease from 71.77% to 73.09%.
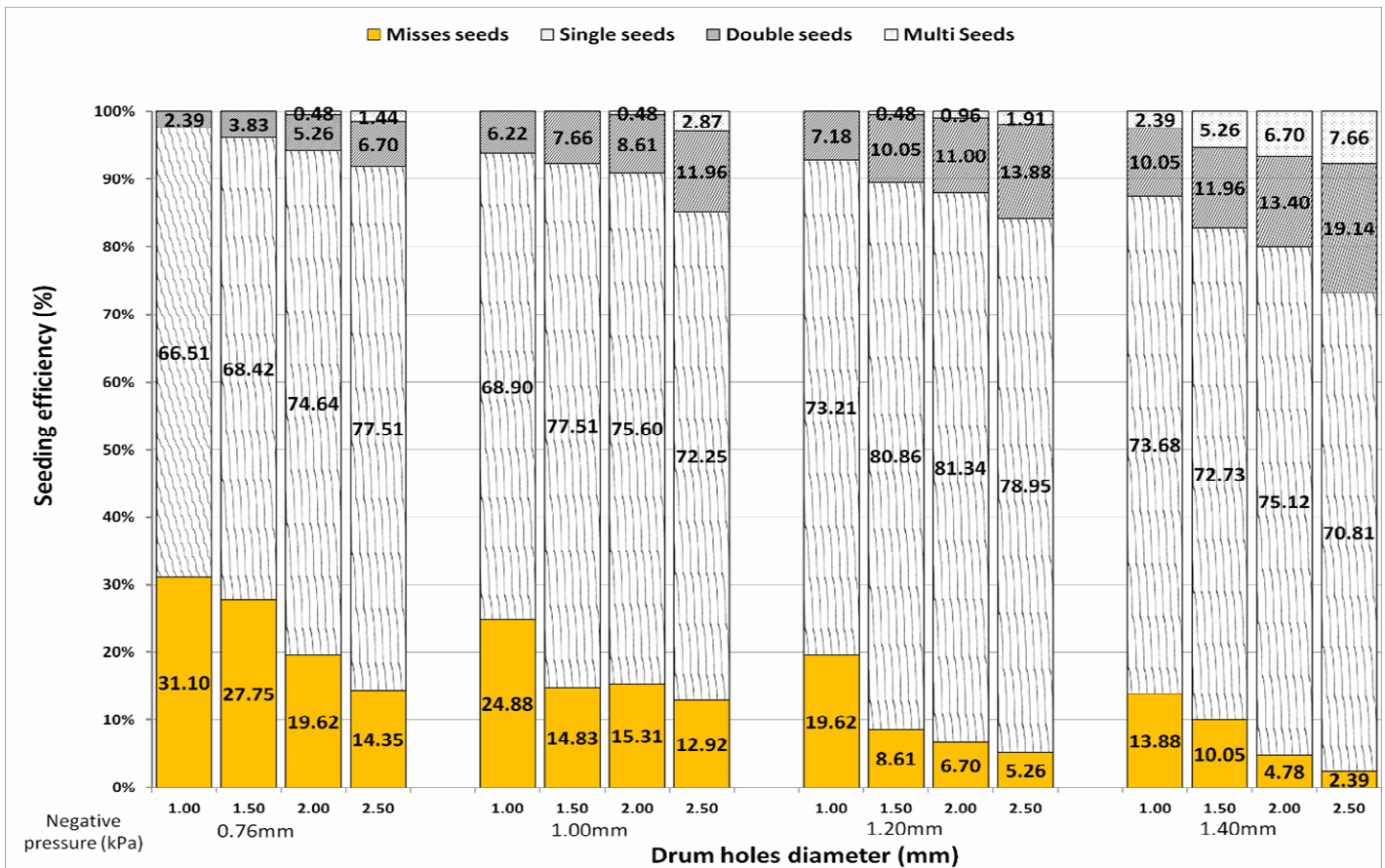
Fig. 11 : The effect of Drum holes diameter and negative pressure on seeding efficiency of tomato seeds

At hole diameter 0.40 mm, the seed singulation ratio increased from 66.51% with increasing percentage of 2.8,10.90,14.2% when increasing the negative pressure from 1.0 kPa to 1.5,2.0,2.5 kPa respectively the other hand at the same pressures, the ratio of missed seeds was increased from 31.10% by increasing ratios of 12.07, 58.54, 116.67%. The high percentage of missed seeds indicate that the hole diameter is not suitable for sowing.

The relation takes the same trend at hole diameter of 0.60mm with increasing percentages of (11.11, 8.86%) when increasing the negative pressure from 1.0 kPa to 1.5and 2 kPa respectively. Then increased by 4.46 % at 2.5 kPa. The relation takes the same trend at hole diameter of 0.8 mm, and 1.00 mm.

From Fig. (11), it realized that the increasing of the negative pressure is increasing the ratio of double and multi seeds comparing to the single seed ratio at the same pressure. At hole diameter 0.4 mm The percentage of double is increased by 1.44%, 2.87%,and 4.31% by increasing the negative pressure from 1kPa to (1.5,2 and 2.5) kPa. The relation takes the same trend by increasing the hole diameter from 0.4mm to (0.6,0.8,and 1 mm) by (18.75%, 27.78% and 48.00%), (28.57 %,34.78% and 48.28 %) and (16.00% ,25.00% and 47.50%) respectively .

Also, at hole diameter 0.4 mm The percentage of double is increased by 1.44%, 2.87%, and 4.31% by increasing the negative pressure from 1kPa to (1.5,2 and 2.5) kPa. The relation takes the same trend by increasing the hole diameter from 0.4mm to (0.6,0.8,and 1 mm) by (18.75%, 27.78% and 48.00%), (28.57%, 34.78% and 48.28%) and (16.00%, 25.00% and 47.50%) respectively .

From Fig. (11), it was realized that the optimum hole diameter for planting the tomato seeds is 0.80 mm operated at negative pressure 1.5 kPa that gave percentage of single seed 80.86%, double seeds 10.05%, multiple seeds 0.48% and missed seeds 8.61%. Also, a random sample of the planted trays was nursed to find out the effect of the machine on seeds variability. The average plants emergence percentage was ($\approx$ 88%).

6. The effect of drum liner speed on seeding efficiency of tomato seeds:

The experiments were carried out to sow cucumber seeds in 209 cells plug trays to study effect the drum linear speed and negative pressure on seeding efficiency with the optimum hole diameter 0.80 mm. The average values of seeding efficiency (%) were monitored with drum liner speed of (0.06, 0.08, 1.00 and 0.12 m/s) by changing the main motor pulley and changing the negative pressure from (1.0 kPa) to (1.5, 2.00 and 2.50 kPa) by adjusting the air inlet valve. The treatments were done to determine the optimum calibration of the negative pressure and the optimum drum linear speed. Fig. (12) shows the effect of drum linear speed and negative pressure on seeding efficiency of the cucumber seeds.

From Fig. (12), it was realized that maximum seed singulation ratio was 85.17% at linear speed 0.06 m/s and negative pressure 2.00 kPa.

Meanwhile, the minimum seed singulation ratio was 55.02% at linear speed 0.12 m/s and negative pressure 2.5 kPa
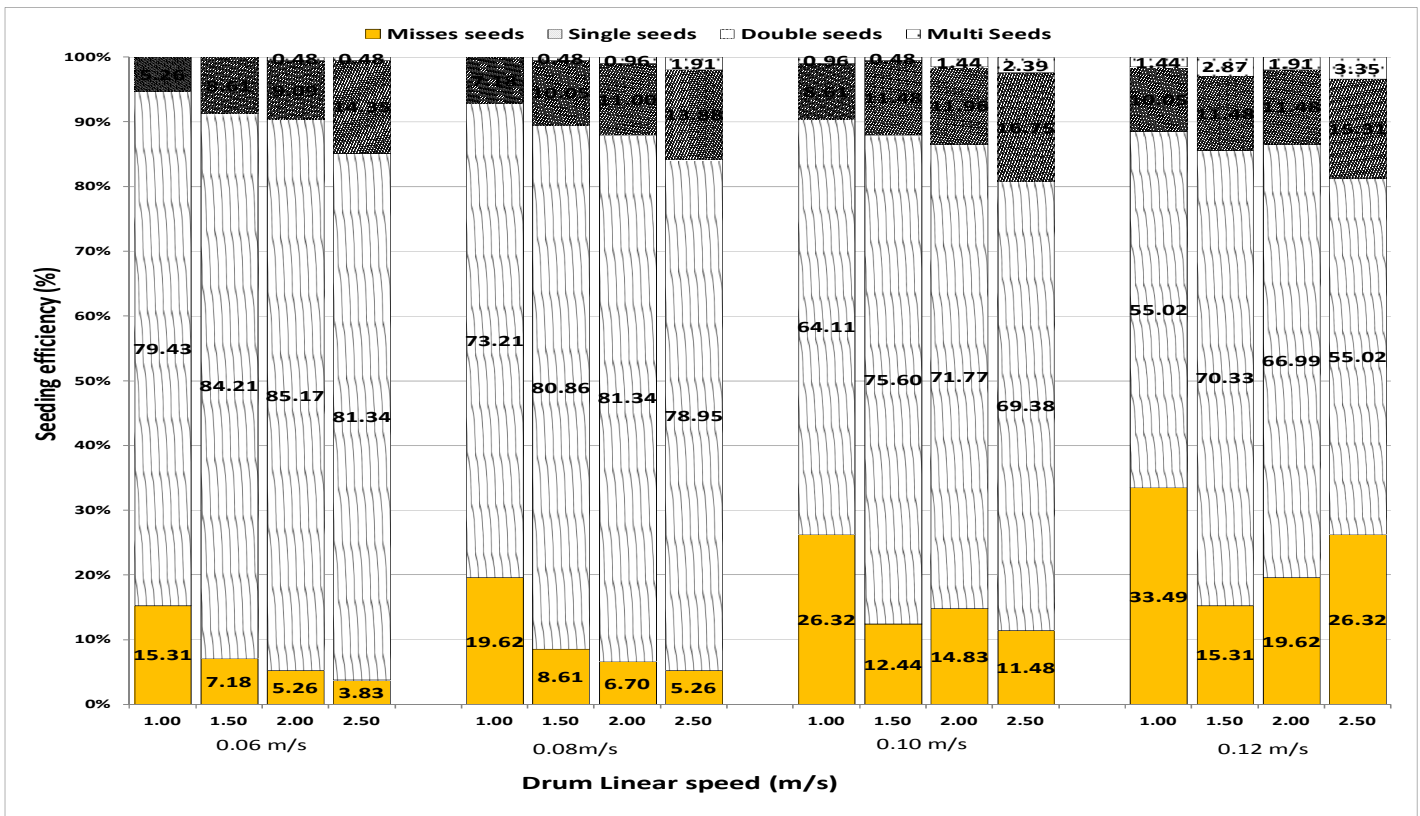
Fig. 12 : The effect of drum liner speed on seeding efficiency of cucumber seeds

From Fig. (12), by increasing linear speed from (0.06 m/s to 0.08 m/s, 0.1 m/s, and 0.12 m/s) the average singulation decreased from 82.54 to (78.59 %, 70.22%, and 61.84%) respectively.

Also, it was found that the double seed average percentage was increasing by increasing the linear speed. By increasing the drum linear speed from 0.06 m/s to (0.08, m/s0.1 m/s, and 0.12 m/s) the average double seeds increased from 9.33 to (10.53 %, 12.20 %and 12.08%) respectively.

The relation takes the same trend with the multi seeds percentage. The multi-seed average percentage was increased from 0.24% to 0.84%, 1.32% and 2.39 by increasing the linear speed from 0.06 m/s to (0.08 m/s, 0.1 m/s and 0.12 m/s) respectively.

By calculation the total number of seeds excluded the single seeds, it realizes the minimum number was 51 seeds at drum linear speed 0.06 m/s and negative pressure 1.5 kPa with sigulatry of 84.21%. At drum linear speed 0.08 m/s and negative pressure 6.00 kPa, the number of seeds excluded the single seeds was 63 seeds with singular of 80.86% with difference of 12seed at drum linear speed 0.06 m/s.

The linear drum speed which synchronized with the tray conveyor is surly will effect on the rate of performance of the machine.

This indicate that, the optimum drum linear speed is 0.08 m/s with negative pressure 1.5 kPa with hole diameter of 0.8 mm that gave 80.86% single seeds,10.05% double seeds ,8.61% missed seeds, and 0.48% multi seeds.

Conclusion

The obtained results can be summarized as following:

1. The metering unit success to plant large seed and small seed in different types of plug trays without changing the drum to suit the trays from 84 to 209. The optimum

drum linear speed for planting the tomato seeds variety of (Super-Marmande) is 0.08 m/s with negative pressure 1.5 kPa with hole diameter of 0.8 mm that gave 80.86% single seeds, 10.05% double seeds, 8.61% missed seeds, and 0.48% multi seeds. Also, the optimum hole diameter for planting the cucumber- seeds variety of (Ghazeer) was 1.00 mm operated at negative pressure 6.0 kPa that gave percentage of 90.48% single seeds, 5.95% double seeds, 3.57% missed seeds, and 0.00% multi seeds.

2. The seed singulation ratio affected by hole diameter and negative pressure value. Both parameters affected by the mass of the seed. Generally, the singulation seed percentage is decreasing by increasing to the hole diameter and negative pressure value.

3. The metering unit success to plant two types of trays without changing the seeding drum. Also, the seed selector plays a big role to decrease the percentage of multi seed.

4. The seed vibrator and air negative distributer are very important to increase the singularly ratio.

5. The metering unit is not affected on the seeds. The germination results indicated that the seedling emergence ratio was the same of the seed germination ratio.

The following conclusions and recommendations can be drawn:-

- 1-The metering unit can be manufactured locally with cheap price for small and medium seedling nursery holders away from electronic parts.

- 2-The metering unit has many variables can affect on the performance of the machine could be studied in the further.

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