INVESTIGATE A PROTOTYPE FOR TOMATOES PRECISION SEEDER

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ABSTRACT

The objective of this research was to design, construct and test a prototype for seeding tomatoes seeds in tray. The fundamental basic of the prototype depending on, using air vacuum to catch single seed from seed tank and put it inside tray cells. The air suction was supplied from a suction pump, whereas the seeds are forced to move from the seed tank towards the seed tube. Three electronically control units were used to send consequence electronic signals. These signals were adapted to put on and cut off air suction, to move the tray belt, and to operate the air pump. The evaluation of the developed unit was carried out in 2012-2014 seasons in soil pen Lab- Agric. Eng. Dept., Mansoura University. The effect of some engineering parameters included four feeding device height, four different levels of orifice positions, four orifice diameters on seeding tube and three air suction pressure on seed catching, doubling and skipping seeds in tray cells. The results indicated that the best feeding device height that fulfill catching one seed per orifice was h =2.2mm at suction tube orifice diameter of 0.5mm and air suction pressure of 33.44mbar. Increasing the orifice diameter to 0.75, 1.0 and 1.5 mm the best (h) were 2.9, 3.2 and 3.9mm respectively. At these operating parameters the results recorded no seeds skipping, and low doubling.

INTRODUCTION

Precision seeding systems using air pressure positive or negative is facing many problems during application. The most important imbalance resulting from the pressure change during the process of seeding, as well as with regard to the possibility of keeping seeds through holes feeder.

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These problems are complicated attempts at agriculture in seeding trays to need of high accuracy during planting, where you must maintain a certain number of catching seeds with pinpoint precision landing in the definite area and not have any unit of the content of the seeds in order to ensure growth replication seedlings.

The metering of the seed flow, has two aspects, the first, metering rate, refers to the number of seeds that released from the hopper per unit time. The second is that, single-seeds must be seeding in precision planters to allow placement of seeds at uniform spacing in each row (Ismail 2004). The percent of cell fill for a given planter influenced by such factors as the maximum seed size in relation to cell size, the range of seed sizes, the shape of the seeds, the shape of the cells, the exposures time of a cell to seed in the hopper and the linear speed of the cell (Kepner et al. -1982). The most uniform seed distribution is usually obtained with combinations of seed size, cell size and cell speed that gave about 100 % average cell fill. The cell diameter or length should be about 10 % greater than the maximum seed dimension and the cell depth should be about equal to the average seed diameter or thickness. Mechanical performance is improved by grading the seed within close size tolerance (Ismail -2008).

Division number on the scale of the measuring device generally affects the consistency of repeated measurements and, therefore, the precision. Since precision is not based on a true value there is no bias or systematic error in the value, but instead it depends only on the distribution of random errors. The precision of a measurement is usually indicated by the uncertainty or fractional relative uncertainty of a value (Eurachem and Citac -2000). Panning et al. (1991) indicated that there are 6 types of precision seeders. Each has advantages and disadvantages. Belt type, plate type, vacuum type, spoon type, pneumatic type and grooved cylinder type. Dongguang Zhang and Yuming Guo (2012) investigated seed-metering device using the movement simulation and module. According to the analysis results, the defaults of the feed device were showed that this device is simple and suitable for the seeding requirements of small grains.

Pickup tubes are drilled with holes to suit the spacing of the plug tray. The seeds are vibrated in a stainless steel seed tray and picked up by vacuum on the holes. The handle is then moved from the pickup position to the discharge position, just above the plug tray. A small hole in the handle is covered to release the seeds onto the surface of the compost. The tray is moved by hand to the next row, and the process repeated. The vacuum and vibration are adjustable for different sizes and weights of seed. İsmet et al. (2012) recorded the upper limit of vacuum plate peripheral speed was found to be 0.34 m s^{-1}. The use of 72 holes instead of 26 holes in the vacuum plate at 6.3 kPa created a vacuum band in the width of 10 mm around holes and this increased multiple seeds index and caused a reduction in seeding performance. For this reason, the use of vacuum plates with 60 or 52 holes is recommended for cotton seed. The forward speed of either 1.0 or 1.5 m s^{-1} was found to be acceptable for the seed spacing of 0.05 and 0.10 m, respectively. On the other side Shaaban et al. (2009) conducted an indoor soil bin facility under different operational parameters. These parameters were three seed plates with different hole diameters (0.8, 1.0 and 1.2 mm), four levels of disc speeds (peripheral velocity of seed plate) (0.08 (7.3), 0.14 (12.5), 0.21 (18.7) and 0.28 m/s (24.4rpm)), four levels of blower speeds (4000, 4500, 5000 and 5500-rpm) and three level of forward speeds (2.7, 3.6 and 5.3 km/h). Results indicated that the optimum values of the actual seed spacing (5.93 mm), seed miss index (8.1%), seed multiple index (8.12%), quality of feed index (83.7%), precision in spacing (23.4%) and the vacuum pressure in the hole (4.75 kPa.) were obtained with the seed plate of 1.0 mm hole diameter (Deyong Yang et al., - 2011).

Tomatoes are very important in the economic point of view due to inordinate of annual worldwide production. In Egypt annually production of it is about 8.105 million tons (statistical FAO, 2011). But, mechanization of tomato seeds planting was facing a lot of problems specially when preparing the seedbed. This is due to the fine weight and seed size. This investigation tries to use air suction pressure to solve these problems.

So, the study aims to design and test a simple prototype to improve and optimize tomato seed catching performance by determining each of proper feeding device height, orifice diameter and proper suction pressure that realize the single seeds per hill on the tray using air suction pump.

MATERIALS AND METHODS

The Designed Unit Operation

During supply suction air from suction pumps to feeding seeds tube, the seeds were pulled from seeding tank to the holes that located on seeding tube (figure 1). After that, the electrical control unit gives signal to feeding tube to move until it reach the end of the cycle, which previously specified when the proposed calibration. Then, control unit set another signal to off the suction air from seeding tube, at this moment; the seeds drop out to tray cells. Then, the control unit sent three consecutive signals. The first is to move the tray belt at the situation that allows transferring the centers of empty cells in tray seeds. The second signal relayed to tube seeds due return to the first mode, which allows catch another seeds. The third signal sent to the air suction device for operating the air pump.

General description of prototype:

As shown in figure (1) the designed prototype includes the following components:-

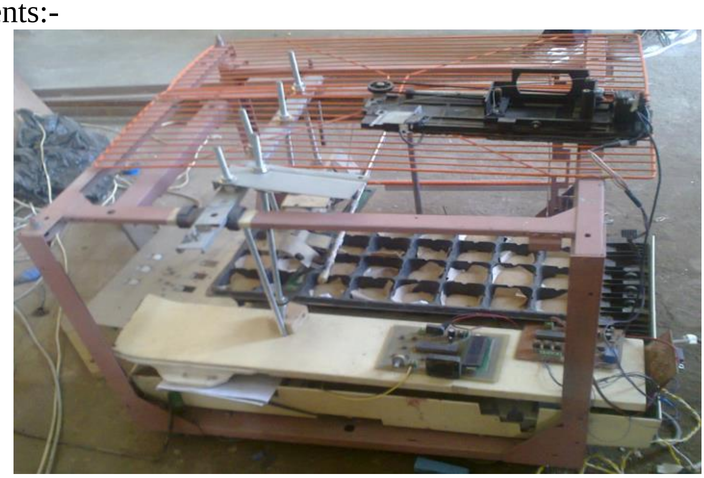


Figure (1): General view of the developed precision seeder

The complementary parts:

Frame: It was cuboids shape, the front and behind surfaces is constructed from equal-sided L shape angle steel with cross section of (25.4 × 25.4mm) and 2.0mm thickness. The front frame has a 600mm side-length and 500mm wide while, the side surface with 600 × 700mm. The base surface is covered with slab sheet with 3.0mm thickness.

Cover sheet: The frame is covered with two sheets for protection. Also, the conveyor chain constructed from galvanize smooth iron sheet (840 × 300mm) with 0.8mm thickness.

Electrical elements: Three main systems were investigated for controlling, checking, adjusting and detecting each of seeds hitching device, tray movement and vacuum systems.

Electrical circuit of seeds catching device: Figure (2) indicated the component of catching device cycles. It used to get motion order for agreement motion device (front or back motion). Also, it used to control a resting time for seeding seeds.

Electrical circuit of vacuum system: It used to off-on the vacuum pump (figure-3) during catching seeds from tank and during seeding it in tray cells.

Electrical circuit of tray motion: It used to send a signal (figure-4) to lead the tray belt one cycle (i.e. moves the center of tray cells in certain position to the following cells center immediately).

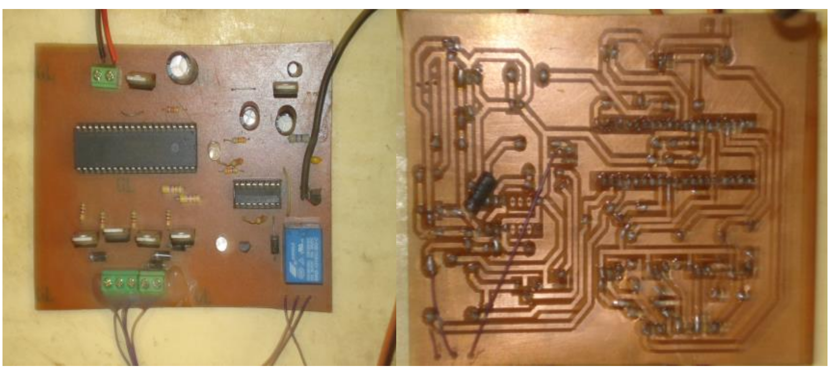


Figure (2): Control **circuit** for feeding seeds devices (stepper)

Transmission system:

The differential system type supplies the electrical power from electrical source to all the movements systems. The gears, belts and chains were used to reduce and to control on the movement parts. The elevator belt has a roller with an elevator chains (claw chains).

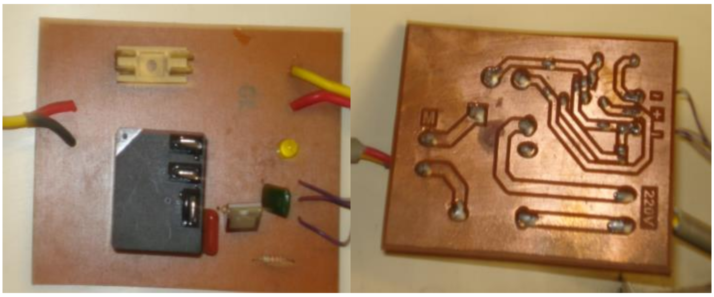


Figure (3): Electrical **circuit** for vacuum system

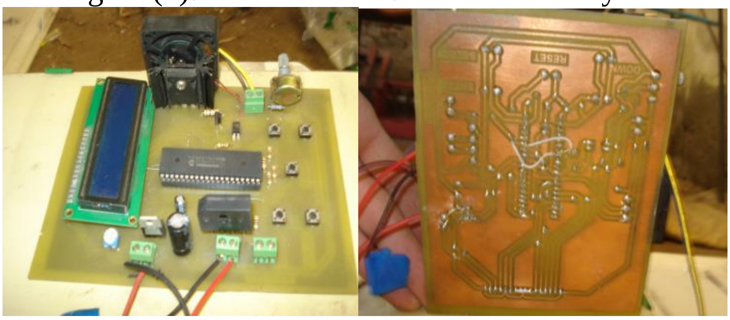
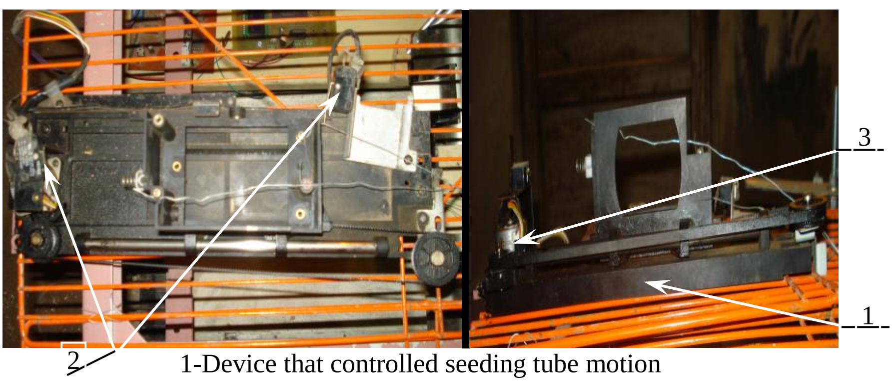


Fig (4): Electrical **circuit** for conveyer belt tray

Header (feeding system head):

The header is used to supply tomato seed to seed bed (tray of seed). It constructed from the following components as shown in figure (5).

The feeding system is consisted of seeds hopper, seeds pickup tube (feeding device) and seeds holders system (vacuum system).



1-Device that controlled seeding tube motion

2- Control sensor, cut the electrical current 3- Stepper motor

Figure (5): Plan and side view of header location

Experiments and Measurements

The tomatoes seeding prototype unit was tested in soil-bin that represents one of the out comes from a projects financed by El-Mansoura University

Researches Unit (title of: Developing the metering unites of the pneumatic planter by supervisors Ismail Z.E Prof. of Power technology and farm machinery, Ag. Eng. Det. (2004). For optimization of affecting the performance of investigated unit, experiments were conducted with four levels of orifice positions (1, 2, 3 and 4) and four orifice diameters on feeding suction tube (0.5, 0.75, 1.0 and 1.5mm) and four feeding device height (0.0, 1.0, 2.0, 3.0 and 4.0mm) under three suction of air vacuum (31.8, 33.44 and 85.1 mbar).

Tomatoes seeds catching: It was calculated by measuring the number of seeds per orifice on the tube of feeding devices. Three replicates for each treatment was carried out.

Seeding tube height: The levels heights of seeding tube were regulated by helping device height. It was calculate the height as differences between the zero level and the certain position.

Suction air pressure: It was measured using special gauge meter with accuracy of 0.01mbar, made in Germany with the maximum values of 1.0mbar.

The factorial design used to evaluate the effect of experimental factors on the designed unit because of the following; first it is a new design and wanted to measure the accuracy of the factors levels and the reaction between it by the same level of accuracy, second it is simple to analysis, third it is very suitable for machines experiments. The different parameters of laboratory experiments were arranged, according to a simple factorial design with three replicates for each one. The results number of units was 720 and 240 units in each replication respectively.

RUSULTS AND DISCUSSION

Optimization of Catching Performance

1- The proper feeding device height

The relationship between feeding device height (h, mm) and tomato seed catching is illustrated in figure (6) under four different levels of orifice positions (1, 2, 3 and 4) and four orifice diameters on feeding suction tube (0.5, 0.75, 1.0 and 1.5mm). Generally, increase the feeding device height decreased the number of tomato seeds catching per hole. For example, by increase the feeding device height from 0.0 levels to 4.0 mm decreased the number of seed catching from “1.24 to 0.0”; “1.2 to 0.0”; “2.32 to 0.0” and “2.32 to 0.0” at feeding diameter orifice of 0.5, 0.75, 1.0 and 1.5mm respectively. Referring to figure (6-A), the general trend of data curve for tomato seed catching (S) rapidly decreased at orifice level position 2 and slowly decreased at each of 3 and 4 of orifice positions. By increase the orifice diameter to 0.75mm the direction of seeds catching curves for all treatments (orifice position) slowly decreased except level position 3 of feeding orifice as shown in figure (6-B). While, during increase the orifice diameter to 1.0 mm the trend curves for orifice position of 1 and 2 were rapidly decreased and vice versa for orifice position of 3 and 4 (figure- 6-C).

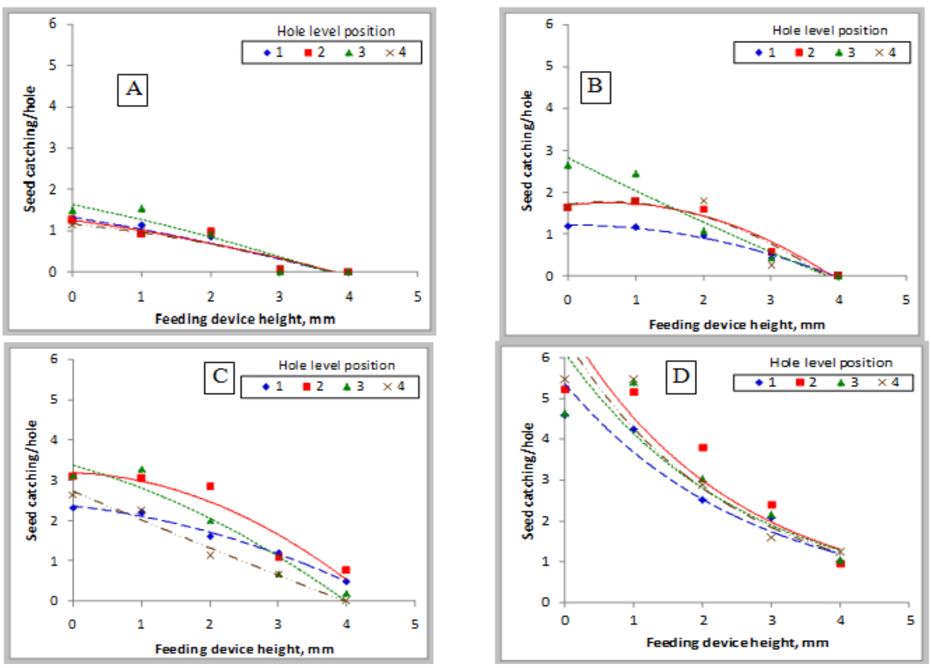


Figure (6): Effect of feeding device height on tomato seeds catching at suction tube orifice diameter of 1.5 mm.

Generally, the maximum of tomato seed catching (S = 5.48 per orifice) was found at zero of feeding device height and 1.5 orifice diameter with the level 4 of orifice position. But, at increasing the feeding device height the minimum of tomato seed catching (S = 1) were recorded at 4 mm of feeding device height and 1.5 orifice diameter with the level 1 of orifice position (figure- 6-D). The dependence of tomato seed catching on feeding device height (h, mm) was further studied using multiple regression analysis. It was found that seeds catching (S) was dependent strongly upon the feeding device height.

From regression equations, it easy to recommend the best feeding device height that fulfill catching one seed per orifice was h = 2.2mm at suction tube orifice diameter of 0.5mm. Increasing the orifice diameter to 0.75, 1.00 and 1.50mm the best (h) were 2.9, 3.2 and 3.9 respectively.

A polynomial regression analysis applied to relate the change in tomato seeds catching per orifice with the change in orifice diameter, feeding device height and orifice levels position. It showed that, there are a highly significant difference between the orifice diameter (positive effect), feeding device height (negative effect) and low significant for orifice level position (positive effect) to the tomato seeds catching. Also the total interaction between different treatments show a significant effect with (R^2 = 0.91) and stander error of 0.61. The obtained regression equation was in the form of:

$$S = 2.84\ d - 0.623\ h + 0.049\ hb \qquad R^2 = 0.91$$

Where: S = Seed catching, number
d = Orifice diameter, mm
h = Feeding device height, mm
hb= Orifice level position, dimensionless

2- The Proper Orifice Diameters.

2-1-The proper orifice diameters as affecting feeding device height

The proper orifice diameters identified as the relationship between feeding device height (h, mm) and tomato seed catching under different variables of air suction pressure as shown in figure (7). Generally, increasing orifice diameters rabidly increased the number of tomato seeds catching per orifice under different of air suction pressure.

For example, at air suction pressure of 31.8 mbar (figure-7-A) and by increasing the orifice diameters 3 times (from 0.5 to 1.5 mm) increased the tomato seed catching 3.929 times at zero level of feeding device.

This ratio increased to 2.73 and 3.19 times at h = 1.0mm and 2.0mm respectively. Nevertheless, it come back to highly increased 32.11 times at h = 3mm. Also, at air suction pressure of 85.1mbar (figure-7-C), by increasing orifice diameters with the above same ratio (3 times) increased seed catching 4.42 times at h = zero. This ratio increased to 6.08 times at h = 1.0mm and come back to decreased (4.84 times) at h = 2mm and return to increase to 7.76 times at h = 4.0mm. The dependence of tomato seed catching on orifice diameter (d, mm) was further studied using exponential regression analysis. It was found that seeds catching (S) was dependent strongly upon the feeding device height. The regression equations as the best fit were placed opposite each draw as shown in figures. The analysis of variance for the data of tomato seeds catching at different orifice diameter (mm), feeding device height (mm) and air vacuum pressure of 31.8, 33.44 and 85.1 mbar indicated a highly significant difference between the orifice diameter and low significant different for feeding device height as presented.

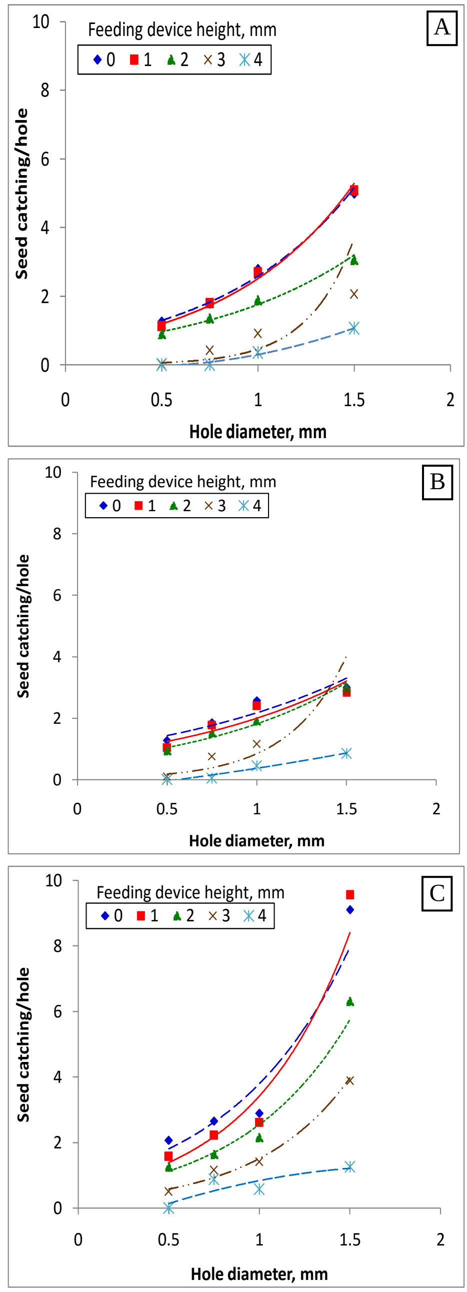


Figure (7): Effect of orifice diameter on tomato seeds catching at different feeding device height

2-2-The proper orifice diameters as affecting orifice level position

The proper orifice diameters recognized as the relationship between orifice level position (hb, cm) and tomato seed catching (S) under different variables of air suction pressure as shown in figure (8). Generally, increasing orifice diameters rabidly increased the number of tomato seeds catching per orifice. For example, at air suction pressure of 31.8 mbar (figure-8-A), by increasing the orifice diameters from 0.5 to 1.5 mm (3 times) increased the tomato seed catching 4.5 times at orifice level position one (hb). This ratio increased to 5.55 at hb = 2 and come back to decreased (4.15 times) at hb = 3. While, at air suction pressure of 33.44 mbar (figure-8-B), by increasing orifice diameters 3 times increased the tomato seed catching 3.65 times at orifice level position "1". This ratio increased to 4.81 times at orifice level position "2". It became decreased to 3.07 times at orifice level position "3". Then, it come back to slowly increased (3.79 times) at orifice level position "4". Meanwhile, at air suction pressure of 85.1 mbar (figure-8-C), increasing orifice diameters 3 times (from 0.5 to 1.5 mm) increased the tomato seed catching 5.64 times at orifice level position "1".

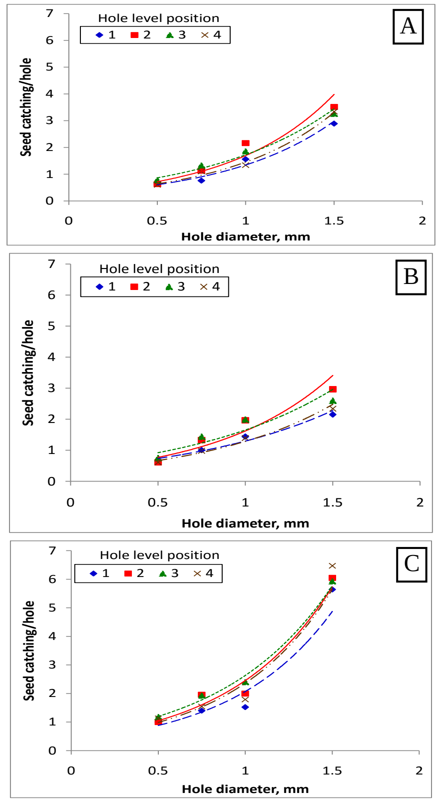


Figure (8): Effect of orifice diameter on tomato seeds catching at different orifice level position

This ratio increased to 6.05 times at orifice level position "2" and come back to decreased (5.01 times) at orifice level position "3" and return to increase to 5.74 times at orifice level position "4". The dependence of tomato seed catching on orifice diameter (d, mm) was further studied using exponential regression analysis. It was found that seeds catching (S) was not dependent upon orifice levels position.

3-The proper suction pressure

To indicate the effect of air suction pressure (p, mbar) during the experimental, a lot of experiments were carried out, the following relationship between orifice diameter (d, mm) and seeds catching under three levels of air suction pressure were identified as shown in figures (9). Referring to figure (9-A), the general trend of data curve for tomato seed catching (S) rapidly increased with increasing air suction pressure at all different orifice diameters. At zero feeding device height and at increasing air suction pressure from 31.8 to 85.1 mbar, the rates of increasing were 1.62, 2.08, 1.12 and 1.82 times at orifice diameters 0.50, 0.75, 1.00 and 1.50mm respectively. But, from figure (9-B), the exponential relation was found, by increasing the air suction pressure from 31.8 to 85.1 mbar increased seed catching from 1.39 to 1.88 times at 0.5 and 1.5 mm orifice diameter. While, during increase the air suction pressure from 31.8 to 85.1 mbar the trend curves of tomato seed catching for feeding device height of 2.0 mm increasing from 0.9 to 1.26 and from 3.06 to 6.31 seeds per orifice (figure- 9-C). The same result was found as shown in figures (9-D) and (9-E).

Generally, increasing air pressure suction increased the number of tomato seeds catching per orifice. For example, at feeding device height of 3.0mm, increasing air pressure suction from 31.8 to 85.1mbar increased the number of seed catching from 0.26 ± 0.45 at orifice diameter 0.5mm. Also, the same trend of results were found at increasing air pressure suction from 31.8 to 85.1mbar, for feeding diameter orifice of 0.75 and 1.00mm, the tomato seed catching increased from 0.76 ± 0.60 and from 1.73 ± 0.97 respectively (figure-9-D). Referring to figure (9-E) the same trend was found but the rate of increasing less than the above relation.

The dependence of tomato seed catching on air pressure suction (mbar) was further studied using exponential regression analysis. It was found that seeds catching (S) was dependent strongly upon the feeding device height. The regression equations as the best fit were placed opposite each draw as shown in figures.

A polynomial regression analysis applied to relate the change in tomato seeds catching per orifice with the change in air pressure, feeding device height and orifice diameter. It showed that, there are high significance differences between the treatments of air suction pressure, orifice diameter and device height to the seeds of tomato catching.

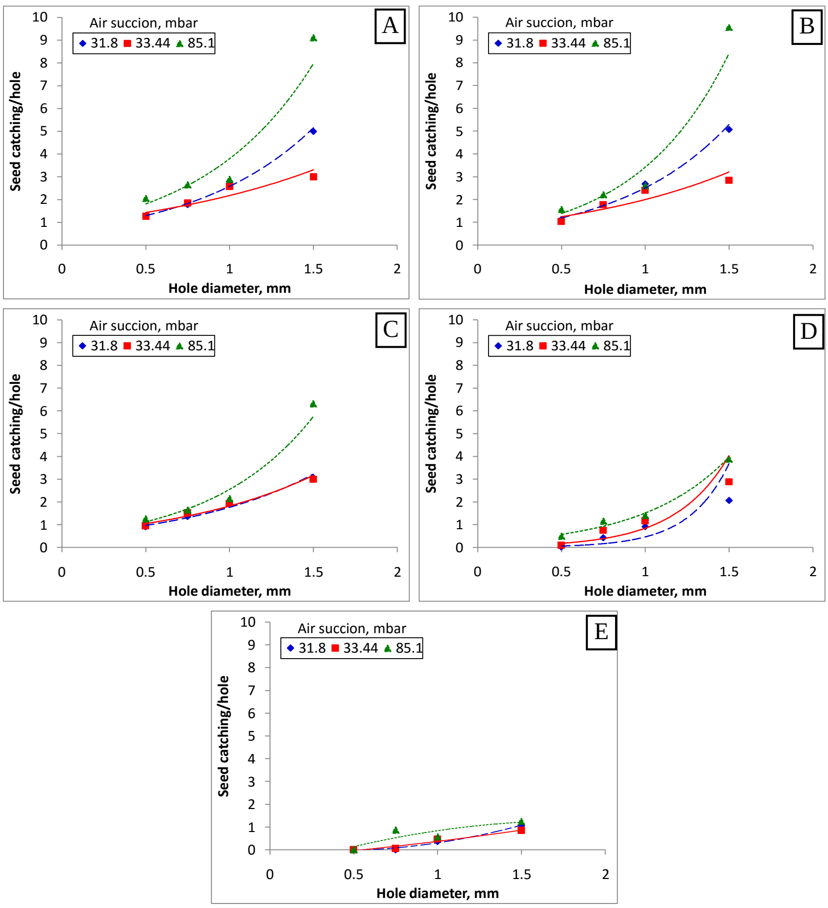


Figure (9): Effect of air pressure suction on tomato seeds catching

Also the total interaction between different treatments show a significant effect with (R^2 =0.7836; 0.8502; 0.8708 and 0.7903) with stander error of

(1.11; 1.05; 0.94 and 1.22) for orifice levels of one, two, three and four respectively. The obtained regression equations were in the form of:

S = 3.034d + 0.019p - 0.231hb R^2 = 0.8676 at feeding device height zero

S= 3.274d + 0.015p - 0.293hb R^2 = 0.8283 at feeding device height 1mm

S = 2.414d + 0.011p - 0.218hb R^2 = 0.8834 at feeding device height 2mm

S = 1.877d + 0.003p - 0.212hb R^2 = 0.8528 at feeding device height 3mm

S = 0.686d + 0.002p - 0.097hb R^2 = 0.7752 at feeding device height 4mm

Regarding to above equations and at orifice diameter of feeding device of 0.5mm and feeding device height of 1mm, the best air suction pressure that recognized one seed per orifice was 33.11 ± 5.86mbar.

4: Skipping and doubling Performance

Data shown in Figure (10) shows the effect of seeds skipping and doubling versus feeding device height (h, mm) and orifice diameters of feeding system at in-let air suction pressure of 33.44 mbar. It can be seen that increasing the feeding device height (h, mm) resulted in a corresponding decrease in the seed doubling and increase seeds skipping at all values of orifice diameters of feeding system. However, the highest seeds skipping values (Sk) were ranged from 0.16 –1.0 which were obtained at 3.0 and 4.0mm feeding device height and orifice diameter of 0.75mm. This trend was also observed at all levels of orifice positions (hb). While, the height value of seed doubling (SD) was observed at zero feeding device height and orifice diameter of 1.5mm for the orifice level position one. Inspection of the data as shown in figures (10-A) showed increase feeding device height from 1.0 mm to 2.0 mm result of skipping in an increase from 0.2 to 0.84 at orifice diameter of 0.5mm and seed doubling decrease from 1.84 to 2.44 at 1.5mm orifice diameter. Also, increases feeding device from 3.0 to 4.0 mm seed skipping increased 0.7% and doubling decreases 16%.

On the other hand, at orifice levels three and four, as showing in figures (10-C) and (10-D) increasing feeding device height decreasing seed doubling by about 89% and 11% at orifice diameter of 1.5mm respectively. But, seed skipping increases by about 7% and 14% respectively.

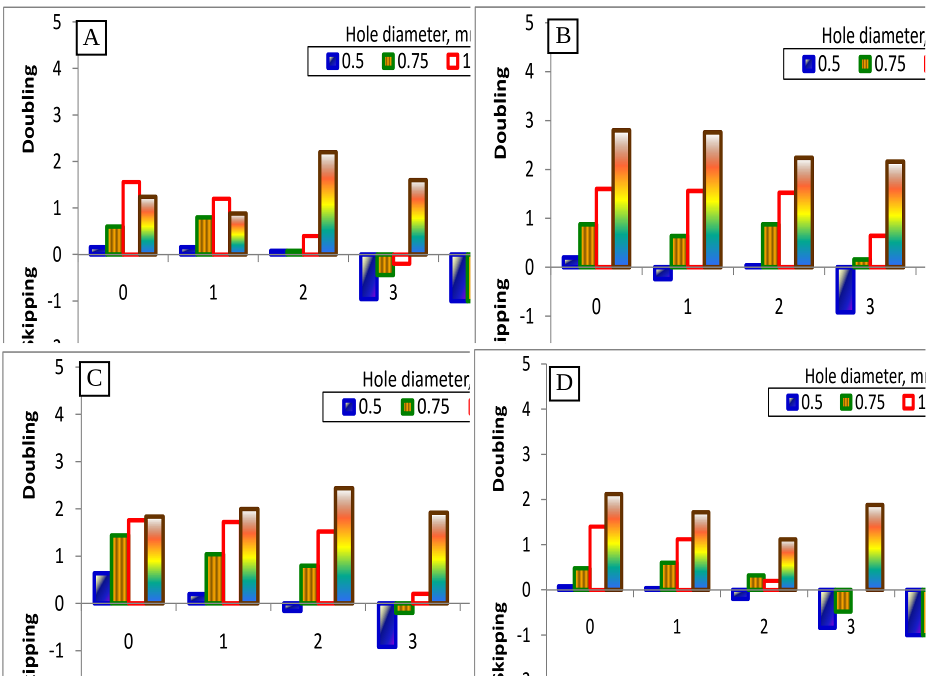


Figure (10): The effect of both feeding device height and orifice diameter on seeds skipping and doubling

CONCLUSION

The conclusions of this paper are summarized as follow:

1- The best value of feeding device height that fulfill catching single seed per orifice was h =2.2mm at suction tube orifice diameter of 0.5mm and air suction pressure of 33.44mbar. Increasing the orifice diameter to 0.75, 1.0 and 1.5 mm the best (h) were 2.9, 3.2 and 3.9mm respectively. At these operating parameters the results recorded no seeds skipping and low doubling.

2- A simple polynomial regression analysis showed that, there are a highly significant difference between the orifice diameter (positive effect), feeding device height (negative effect) and low significant for orifice level position (positive effect) to the tomato seeds catching.

3- Also, at orifice diameter of feeding device of 0.5mm and feeding device height of 1mm, the best air suction pressure that recognized one seed per orifice was 33.11 ± 5.86mbar.

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الملخص العربى

اقتراح نموذج لألات الطماطم الدقيقة

زكريا ابراهيم اسماعيل* مصطفي محمد أبو حباجة**
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يهدف البحث إلى تطوير وتصنيع واختبار أداء نموذج أولي لبذر بذور الطماطم بشفط الهواء في صواني الشتل. والفكرة الأساسية لهذا النموذج الأولي تعتمد على استخدام خاصية شفط الهواء للقط بذرة واحدة من خزان البذور ثم وضعها داخل خلية صنيه الشتل. وأثناء شفط الهواء باستخدام مضخة شفط يتم تغذية أنبوبة البذور، حيث يتم شفط بذرة من خلال كل ثقب على أنبوبة البذور من خزان البذور ثم يتم تحرك أنبوبة البذور إلى موضع ترك البذور فوق خلايا صنيه الشتل من خلال إشارة إليكترونية ثم من خلال إشارة أخرى يتم فصل وحدة الشفط عن العمل لحظياً لتسقط البذور في خلايا صنيه الشتل والتي تم معايرتها مسبقاً. ثم تعطى وحدات التحكم ثلاث إشارات متتالية الأولى لتحريك سير حمل الصنيه والثانية لإعادة ماسورة البذور إلى موضعها فوق الخزان والثالثة لتشغيل مضخة شفط الهواء لشفط للقط البذور مرة أخرى. وقد تم اختبار الآلة وتطويرها فى معمل اختبار الآلات- بقسم الهندسة الزراعية – جامعة المنصورة خلال مواسم ٢٠١٢ – ٢٠١٤.

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تم تقييم الأداء النموذج الآلي المقترح تحت متغيرات هندسية مختلفة عل النحو التالي:

١- ارتفاع ماسورة البذور عن سطح الطبقة البذور (صفر – ١ – ٢ – ٣ – ٤ مم)
٢- بعد ثقب الأنبوب عن وحدة الشفط (١ – ٢ – ٣ – ٤)
٣- قطر ثقوب اللقط (٠,٥٠ – ٠,٧٥ – ١,٠٠ – ١,٥٠ مم)
٤- قوة شفط الهواء (٣١,٨ – ٣٣,٤٤ – ٨٥,١ مللى بار)

وتم دراسة تأثير تلك المتغيرات على:

١- عدد البذور التى تم لقطها.
٢- تعدد أو فقط البذور بالخلية.

ونتج من التجارب أن أفضل قيمة لإرتفاع ماسورة لقط البذور والتي تسمح بلقط بذرة واحدة لكل ثقب ٢,٢ مم وذلك عند ثقب لقط بقطر ٠,٥ مم وضغط شفط ٣٣,٤٤ مللى بار. ومع زيادة ثقب اللقط إلى ٠,٧٥، ١,٠٠، ١,٥٠ مم وكان أفضل ارتفاع ماسورة لقط ٢,٩، ٣,٢، ٣,٩ مم على التوالى. عند كل مستويات متغيرات الدراسة السابقة لوحظ عدم وجود فقد للبذور ووجود تعدد طفيف.