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DEVELOPING THE METERING UNIT OF THE PNEUMATIC PLANTER
2- THE INJECTION PLANTING SEED

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ABSTRACT

This study is part of out comes from a projects financed by researching unit of Mansoura University. Spacing uniformity, seed volumetric rate and irregular depth of seeds in soil for wheat and sorghum are the most common characteristics used to evaluate the injection planter performance. The injection mechanisms speed, level of air pressure, the shape and the size of orifice head and the seed bulk density may all influence seed singulation and placement the seeds. The theoretical studies were carried out on the seed speeds during came out from the injection device nozzle until moment of the seed calmed in the soil. The amount of volumetric flow rate "seed/s" is direct proportional to the injection pressure and also to the seeds density (the flow rate of sorghum largest than the wheat seeds) and inversely proportion to the orifice diameters. Also the seed spacing in row increased with the increase of planting speed and pressure. The statically analysis confirm that the seeding speeds (m/s) have a major effect on the seed miss and double index.

Key words: planter, seed device, pneumatic, single seed disc and systems analysis of seed feeding

INTRODUCTION

In Egypt, the agricultural land can be divided in to two widely types. Namely, the old land (Delata land) lies around the Nile River and the New land (desert land). Planting the desert land faces two big problems. The first is that, this land need the completely mechanization system to precision the seed in a certain time with uniformly distribution. The second is, how do to reduce the potential of soil erosion due to wind and water. Also in old-land, especially after harvesting some crop, the farmers tend to reduce the soil plowing. To solve these problems, many researchers such as Yousef-Zadeh *et al.* (2001), Ismail (2004) and Ismail (2007) investigated the no-till as one of successful planting methods. Nevertheless, the problems now, how use are the no-till to solve the above problems. In addition, what is considering the best?

This paper investigated the injection planting seed as one of best solution. There are two major types of precision seeders: belt seeders and vacuum seeders (sometimes called air seeders). The belt seeders use a rubber belt with holes punched in it to pick up the seeds and carry them to the discharge point. Because the seeds must fit singly into the holes for proper metering, whole size is critical and it may be necessary to have different belts even for different cultivars of the same crop. Nonetheless, these systems did not achieve injection system. Vacuum seeders have a fan that draws a vacuum on the backside of a metal seed plate. The holes in the plate are smaller than the seeds so that the seeds do not pass through the holes, but rather are held against the holes in the plate as the plate revolves. In most cases, a puff of air is provided to ensure a positive release of the seeds at the correct point. Whole size is less critical for vacuum seeders. This system is considered as injection system.

In crop production, the main condition for high productivity depends on seeds being in the optimum living area. In other words, it is necessary for seeds to be placed at equal intervals within row. With uniform spacing, the roots can grow to a uniform size (Karayel and Ozmerzi-1999 and Pannig et al. -2000). Although there are many planters having different seed metering units, the application of pneumatic single seed planters has rapidly increased due to the fact that their seeding performance is better than that of the others. In additions, the devices of mechanical seed metering used in conventional drills are not capable of operating at high travel speed (Soza *et al.* - 2007). FMO (1981) said that the air system, pressure or vacuum, may be used to meter many different kinds of seeds. The changes required to go from one crop to another involve matching the size openings in the metering wheel or drum to the seed. Another requirement is matching the pressure differential to the density or mass of the seed. While, EL-Shal (1987) showed that the commonly used volumetric metering systems would not sufficiently meet the objectives of the research. Study was carried out to determine the minimum nozzle air velocity to lift up one seed, assuming that the seed closes nozzle completely. This assumption is not fare because of the suction air force able to pick up the seed if the suction force is largest than the exhaust force.

The conveying seeds by positive pneumatic air face many factors affecting the force of conveying (Ismail-2004). The shape and size of seeds, the shape and diameter of inlet orifice diameters and the radius of outlet orifice of seeding metering are considers as the main static factors influence of the conveying force. While, the amount positive pressure, seed mass and liner velocities of planter are considers as the dynamic factors.

Therefore, this paper aims to:

1- Use the positive air to inject the seeds behind the shoe furrow opener as a new investigating to plant seed.
2- Studies the effect of seed types on the parameters affect the investigated unit performance.

Design consideration

The expected design of injection seeding metering device is set vertically, and the seeds are provided with indented air delivery. A single seed is fed to the seed tank bottom, which transmit by the rotor to injection tube. Then, the seed is forced by the positive air pressure which conveyed it to go out from the orifice nozzle of the injection tube (Fig. 1). The seed leaves the injection tube penetrates the soil surface under the inertia speed to certain depth. Under this condition the seed is exposed to different speeds every cycle of feeding system. Mainly, there are three seed speed levels namely:

1- The seed speed at which the seed leaves the injection nozzle (S_1).
2- The seed speed at moment of seed leaves the injection tube until impact the soil surface (S_2).
3- The seed speed at which the seed penetrate the soil until certain depth (S_3)

To meet the aim of this paper a theoretical analysis was conducted to deal with the machine design parameters.

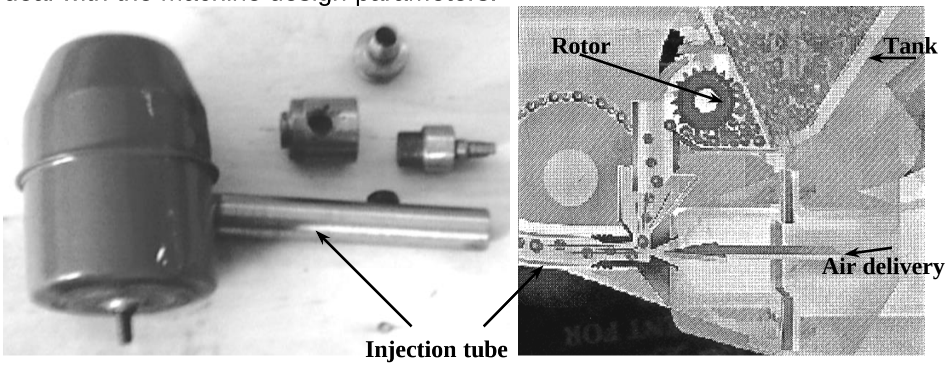

Fig. (1): The injection seed metering device

First situation of seed speed (S_1)

Primary observation during operation the injection system indicated that the seed conveyed to carry out from the orifice of injection tube nozzle under the positive of air pressure. Under this condition many factor affecting the seed speed; such as seed density, orifice area, and the volumetric seed rate.

The volumetric flow rate "VFR" kg/s or number of seeds per unit time were determining from the principle equation of flow rate, which it take the following form:

$$VFR = \eta\ \rho\ A S_1$$

Then,

$$S_1 = \frac{VFR}{\eta\ \rho\ A} \qquad (1)$$

On the other hand, the speed of seed out from the orifice of the injection device theoretically was calculated according to air flow pressure inside the injection device from the following equation,

$$S_1 = C_d\ .\ \sqrt{\frac{2\,\Delta p}{\rho}} \qquad (2)$$

Where;

ρ = The bulk density, kg/m^3

A = Orifice area of gate out, m^2

S_1 = The speed of seed out from the seed out let, m/s

η = The regression constant ratio.

C_d = Constant relative to coefficient of material flow index,

Δp =The differences between inside and outside the orifice pressure

Second situation of seed speed (S_2)

Theoretically, the initial speed of seed falling (S_1) at the moment of leaving the orifice of nozzle and take its way to out may be calculated from equation 2. Referring to Fig. 2 and resolve “S_1” into components “S_1x” and

"S_1Y" relative to the two coordinates "X" and "Y", the motion of the seed is considered a linear motion with a uniform acceleration in direction of "Y" axis. Then,

$$S_2^2 = S_{1Y}^2 + 2gH \qquad (3)$$

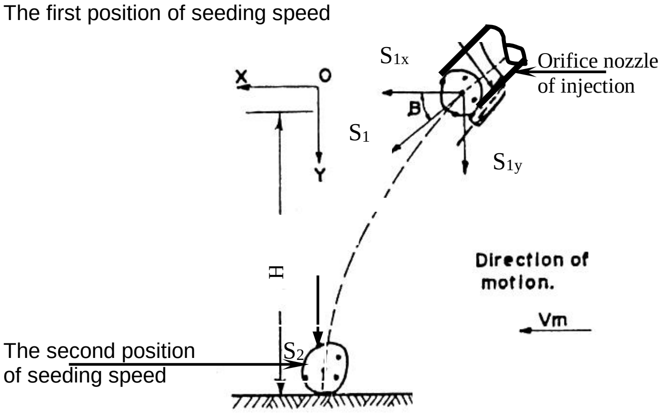

Fig. 2: the seed at mount of falling from the feeding device

Substituting the values of "S_{1Y}" in Eq. 3, then

$$S_2^2 = S_1 \cos\alpha + 2gH$$

$$S_2^2 = \left[C_d \sqrt{\frac{2\,\Delta P}{\rho}} \cos\alpha \right]^2 + 2g\ H \qquad (4)$$

The kinetic energy "I_t" relative to the impact of the seed on the soil surface may equal "1/2 m S_2".
Substituting the value of "S_2" from Eq. "4". Then,

$$I_t = 0.5\ m\ .\left[\left[C_d \sqrt{\frac{2\,\Delta P}{\rho}} \cos\alpha \right]^2 + 2g\ H \right]^2 \qquad (5)$$

Where:

S_2 = Impact speed of seed on the soil surface, m/s
= (the second situation of seed speed)

S_{1Y} = seed speed at moment injected from the seed device
= $S_1 \cos \alpha$

H = The vertical displacement of seed, m

α = Seed falling angle, degree

m = The seed mass, g

g = The gravitational acceleration, 9.81m/s^2

The maximum impact of the seed will occur at the maximum of "P", "α", C_d and "m". The value of "I_t" is found to be 0.051 J at linear speed of machine = 0.25 m/s; g= 9.81 m/s; α = 30°; S_1 = 0.1 m/s and m = 0.05 g. ΔP=1.5 kPa; ρ =

718kg/m^3; C_d=85% and H= 0.25m. Then the penetration force upon the soil surface is about 0.51 N.

Third situation of seed speed

Logically, as shown in Fig. 3, the seed during dives in soil until the moment of its calmed it will expose during penetration to;

a) Friction force between the seed and the surrounding it soil.

b) The mass of seed.

By taking the force vectors in the direction of "OY" axis as shown in Fig. 3 the equation of Newton dynamic may be rewritten in the following pattern:

$$m\,a = m\,g - F$$

$$m\frac{dv}{dt} = m\,g - F \qquad (6)$$

Multiplying equation "6" by "dt" and integrating from initial speed of seeds "S_2" have the vales at initial time "t_0 = 0" to the maximum speed S_3 at maximum time of conveying the seed until the seed is calm down in the soil "t". Then,

$$\int_{v_1=S_2}^{v=S_3} dv = \int_{t_0=0}^{t} g\,dt - \int_{t_0=0}^{t} \frac{F}{m}\,dt \qquad (7)$$

$$S_3 - S_2 = g\,t - \frac{F}{m}t \qquad (8)$$

Seed calming down depth "d" (Fig. 3) may be obtained by integrating the Eq. 8 relative to the dropping time "t".

Then,

$$\int_{d=0}^{d} dd = \int_{t=0}^{t} [g\,t - \frac{F}{m}t]\ dt \qquad (9)$$

$$d = \frac{g\,t^2}{2} - \frac{F\,t^2}{2\,m} \qquad (10)$$

Then the resistance force "F" values is equal

$$F = m\,[g - \frac{2\,d}{t^2}] \qquad (11)$$

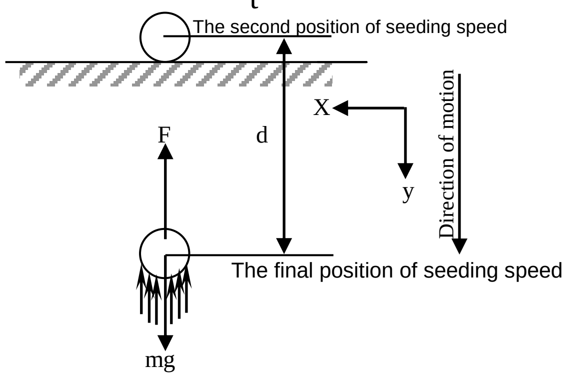

Fig. (3): The factors affecting the depth of seed in soil

Eq. 11 may be used to determine the resistance force (F), if data are available for “m”, “g”, “d”, and “t”. For sorghum seed an example, let us assume that m = 0.05 gram, g = 9.81 m/s^2, d = 15 cm and t = 0.25 s. Then F = 0.949 N and the negative sign means that the direction of “F” force in the opposite direction of seed motion.

MATERIALS AND METHODS

The paper was carried out on a new device of the injection planting seed. The tests unit designed by the author (Ismail-2004) at the Agriculture Engineering Workshop of Mansoura University. This study is part of out comes from a projects financed by researching unit of Mansoura University.

The principle configuration of the Test-Trolley

The injection device was laboratory tested in Trolley-Lab recognized by Ismail (2004) at Ag. Engineering Department in Mansoura University. The Lab was supported by Test-Trolley as shown in Fig.4. The Test-Trolley consists of three meanly parties, namely, the soil-bin, the mobile trolley and the transmission systems. The soil bin having a basin made from iron sheet with channel form. It equipped with 6 U-section stands to carries the basin. The basin is denominated the soil bed. The mobile trolley is considered the base at which the investigated device tied on it. The motion was supply to trolley by close transmission wire system (Fig. 5). To over com the trolley motion resistance, four bearing were fixed on the rod of soil bin. The case of bearing was designed to easy run on the two parallel rail rods. The Test-Trolley was powered by electrical motor of 10 kW, which transmission the motion to the trolley by two individual reductions gear box to simulate the speed of the injection seeder in the field.

The principle configuration of injection seed metering

The injection seed metering device having a tank, metering unit and axial air divider (Fig. 1). The major parts of injection metering unit are the lever, rotor and injection tube.

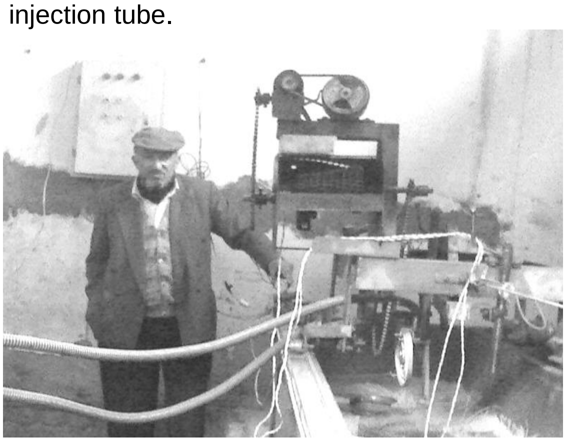

Fig.(4): The Test-Trolley lab (Ismail- 2004)

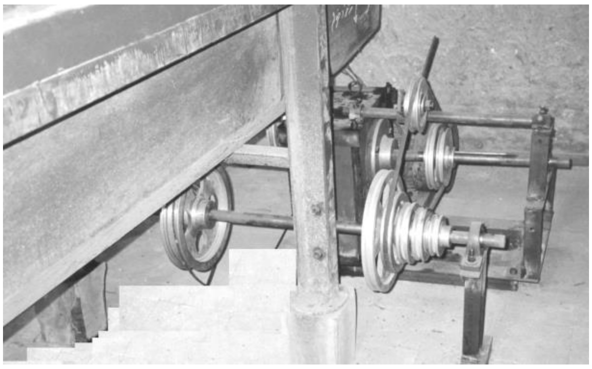

Fig. (5): The transmission motion system to the trolley

Based on the uniformity of seed injection, seed rate, number of missing droppings and the device capacity were determined for sowing wheat and sorghum. The physical properties of grains used are tabulated in table 1.

Three levels of air pressure 20; 25 and 35 kPa and two entry shapes seed-hole of the injection tube (D_1= 8mm and D_2 = 12mm) as shown in Fig.6 were identified. The tests were replicated three times for each treatment of injection devices. The volumetric flow rate of seed "VFR" (seed/sec) were measured under different independent factors. The data were statistically analyzed to determine the effect of hole diameter of the seed orifice device, positive pressure and the linear speed of injection device on performance indices, namely mean seed spacing, miss index, multiples index, quality of feed index and depth of seed irregularity.

The seed speed out from the injection device orifice is depended on two mean parameters. The first is the configuration of orifice and the secant is the air caring pressure. The volumetric flow seed rate me be calculated from Eq. (1).

Table (1): Same of the main properties of used grains

physical properties		Wheat	Sorghum	
Dimensions, mm	**Length**	5.58	**Diameter, mm**	3.4
	Width	1.42		
	Thickness	1.24		
	Moisture content, %	18.45	19.22	
Particle equivalent diameter, mm		3.65	-	
Bulk density, kg/m^3		31.50	42.4	
Test mass per 1000 grain, g		48.80	52.64	

The miss index (M_I)

The miss index (M_I) is the percentage of spacing greater than 1.5 times the set planting distance "S_p" in mm, which equal

$$M_I = \frac{n_1}{N} \quad (12)$$

Fig. (6): The inclination curve of seed out for metering device after deletion the rotor unit

The multiple indexes (M_2)

The multiple indexes (M_2) is the percentage of spacing that are less than or equal to half of the set seed distance "S_p" in mm;

$$M_2 = \frac{n_2}{N} \tag{13}$$

Where;

n_1 = the number of spacing ≥ 1.5 S_p
S_p = the set planting distance
N = the total seed number during test
n_2 = the number of spacing ≤ 0.5 S_p

Quality of feed index "QFI"

The quality of feed index is the percentage of spacing that are more than half but not more than 1.5 times the set seeding distance "S_p" in mm. The quality of seed index is as alternate way of presenting the performance of misses and multiples

$$QFI = 100 - (M_1 + M_2) \tag{14}$$

The precision in spacing "PS"

The precision in spacing "PS" is a measure of the variability (coefficient of variation) in spacing "d", between seeds after accounting variability due to both multiples and misses.

$$PS = \frac{Sd}{S_p} \tag{15}$$

Where; Sd is standard deviation of the spacing more than half but not more than 1.5 times the set spacing "Sp" in mm. Uniformity of flow seed distribution was calculated according to ASAE standard (2003).

Statistical Analysis

The obtained data for injection metering mechanism of serials seeds were analyzed using program of Microsoft Excel to determine the significant factors affecting the performance of metering device in lab.

RESULTS AND DISCUSSION

Factors affecting the volumetric flow rate "VFR"

One of the most factors affecting the volumetric flow rate "VFR" of seeding during the injection from the orifice nozzle is the orifice area (referring from the Eq. (1). Fig. (7) illustrates the relationship between the orifice nozzle diameters and the amount of volumetric flow rate "VFR" at different pressure. The general trend of the above relation is that the amount of "VFR" seed/s is direct proportional to the injection pressure and also to the seeds density (the flow rate of sorghum largest than the wheat seeds) and inversely proportion to the orifice diameters.

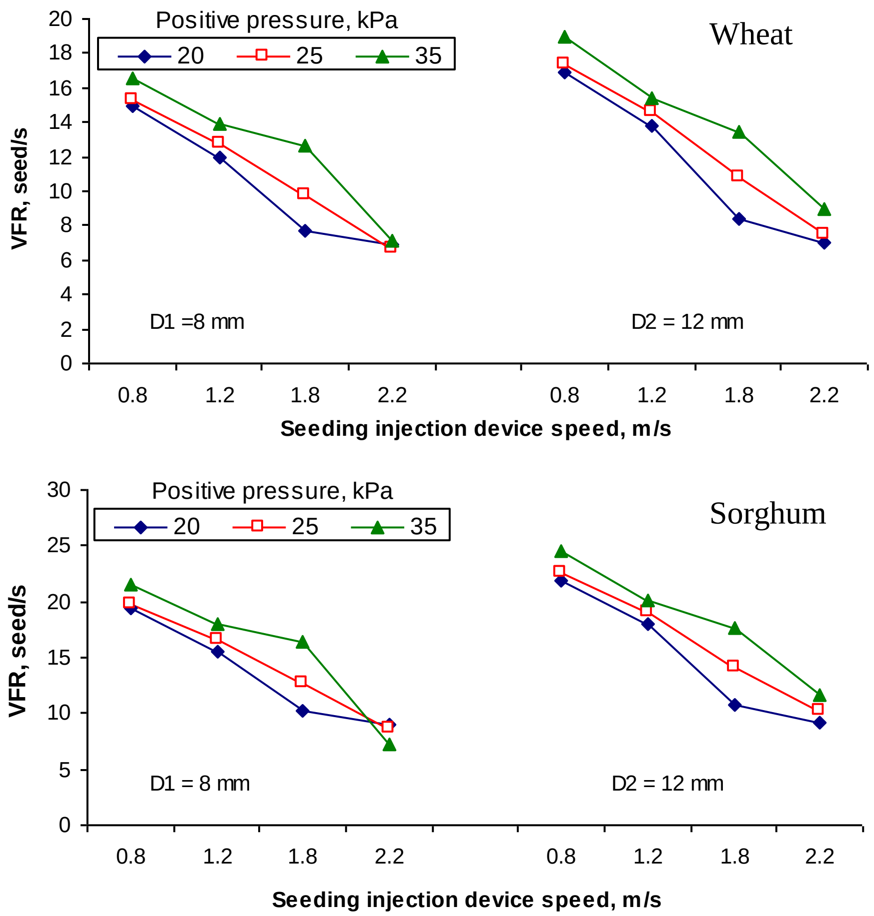

Fig. 7: The VFR via linear speed of injection metering device.

For example, the VFR of 10 seed, were found for D_1 = 8 mm at 1.4 m/s positive pressure of 20 kPa for orifice diameter of 12 mm. While the same result was found at 1.6 m/s and 20 kPa for D_1 = 0.8 mm.

A regression type of polynomial analysis was applied to relate the change in "VFR" under the effect of each of injection device speed (V) and different injection pressure (P) at different injection nozzle diameters (D_1=8 and D_2= 12mm). The obtained regression equations were in the form of:

$Q = 12.700 - 6.47\ V + 0.26\ P - 0.0017\ P^2 + 0.35\ D$ $R^2 = 0.961$ for wheat

$Q = 14.698 - 8.53\ V + 0.46\ P - 0.0048\ P^2 + 0.51\ D$ $R^2 = 0.948$ for sorghum

Fig. 8 shows the relationship between the actual and predicated values from above equations for wheat and sorghum seeds. From Fig. it is clear that the values of equation (predicted values) nearly to close with actual and the trend line for above equations have 45° inclined with x axis (actual data).

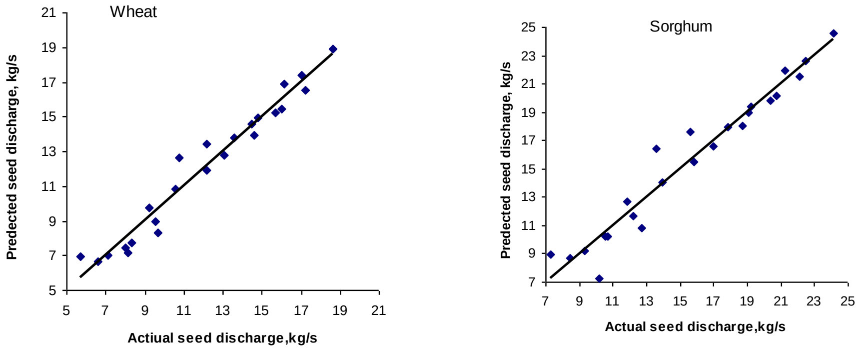

Fig. 8: The relationship between the actual and predicated values from above equations for wheat and sorghum seeds.

Factors affecting the seed dispersions

Experiments was proceeded to test and evaluate the performance and efficiency (seed space, cm; seed miss, %; seed multiple, % and quality of feed indices) of an injection pressure of seeding machine in laboratory. Fig. (9) illustrates the relationship between the seeding device speed (m/s) and the seeding spacing at different positive pressure (20, 25 and 35 kPa).

The general trend of this relationship is that the seed spacing increase with the increase of planting speed and pressure. Increasing the pressure; the average of seed spacing between the seeds on line become near to the theoretical adjusted span (25 cm) for wheat seed. The maximum seed dispersion was 23.4 cm at injection seed speed of 2.2 m/s and pressure of 20kPa, while, the minimum value was 15.4 cm at speed of 0.8 m/s and pressure of 35 kPa. The theoretical seed spacing (15 cm) was found at 0.51 m/s speed and pressure of 32 kPa and D = 8 mm nozzle diameter. Fig. (10) illustrates the relationship between the actual and predicted values of the seeds distribution for the equation of wheat and sorghum seeds.

A regression type of polynomial judge analysis was applied to relate the change in "distance between seeds in row" under the effect of each of injection device speed (V) and different injection pressure (P) at different injection nozzle diameters (D_1 = 8 and D_2 = 12 mm). The obtained regression equations were in the form of:

Seed space = 18.82 + 2.57 V - 0.33 P + 0.003 P^2 + 0.28 D R^2 = 0.92 for wheat

Seed space = 29.87 + 4.44 V - 0.48 P + 0.003 P^2 + 0.52 D R^2 = 0.95 for sorghum

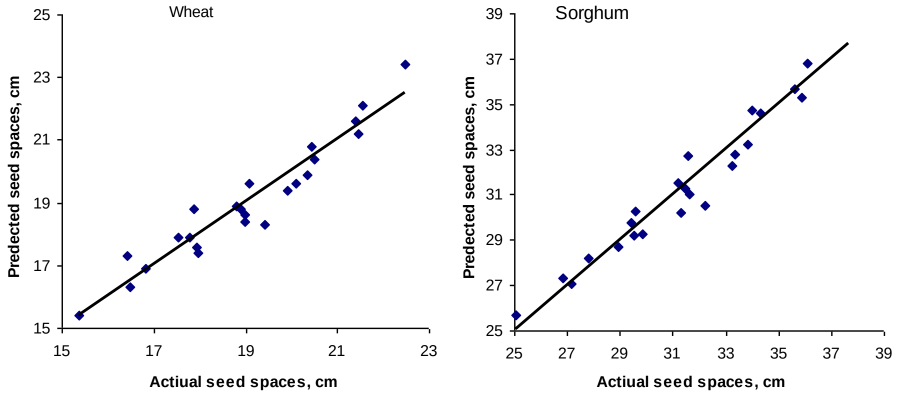

Fig. 9: The relationship between the actual and predicated values from above equations for wheat and sorghum seeds.

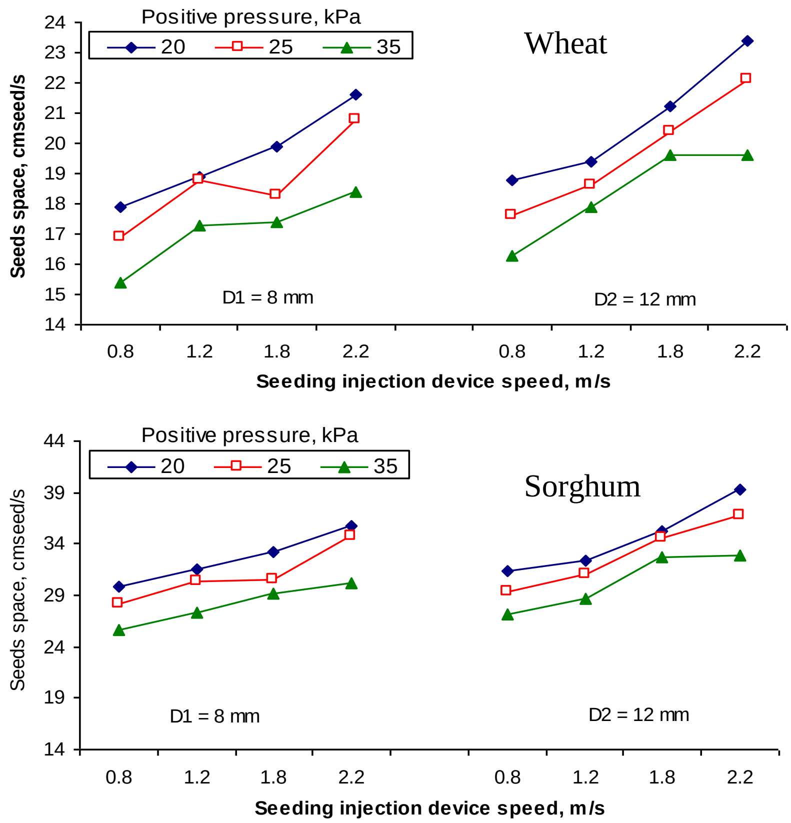

Fig. 10: the seeding spacing in row via the injection device speed

The relationship between the seeding device speed (m/s) and the seed miss index at different injection pressure (20, 25 and 35 kPa) was identified as shown in Fig. (11). The seeding speeds (m/s) have a major effect on the seed miss index. The general trend of this relationship is that the seed miss index "%" increases with the increase of planting speed and decreases with the increase positive pressure. The maximum seed miss index was 9.6 % at speed of 2.2 m/s and pressure of 20 kPa, while, the minimum value was 0.23% at speed of 0.8 m/s and pressure of 35 kPa for wheat seed.

A regression type of power analysis was applied to relate the change in seed miss index under the effect of seeding device speed at different positive pressure. The obtained regression equations were in the form of:

Miss = 10.63 + 3.96 V - 0.76 P + 0.01 P^2 $R^2 = 0.94$ for wheat

Miss = 00.45 + 3.98 V - 0.14 P + 0.01 P^2 $R^2 = 0.93$ for sorghum

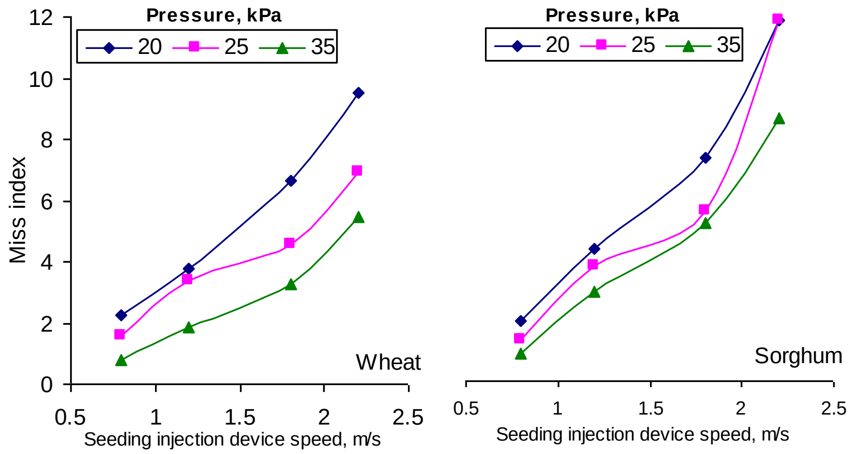

Fig. 11: Effect of injection device speed on the seed miss index.

The relationship between the seeding device speed (m/s) and the seed multiple index at different injection pressure (20, 30 and 35 kPa) was identified as shown in Fig. (12). The general trend of this relationship is that the seed multiple index increases with the increase of seeding device speed and with the increases positive pressure. The maximum seed multiple index was 10.57 % at device speed of 2.2 m/s and pressure of 20 kPa, while, the minimum value was 1.25 at device speed of 0.8 m/s and pressure of 35 kPa.

A regression type of power analysis was applied to relate the change in seed multiple index under the effect of seeding device speed at different positive pressure. The obtained regression equations were in the form of:

Multiple = -12.998 + 2.83 V + 0.80 P - 0.01 P^2 $R^2 = 0.94$ for wheat

Multiple = - 5.74 + 1.95 V + 0.32 P - 0.004 P^2 $R^2 = 0.92$ for sorghum

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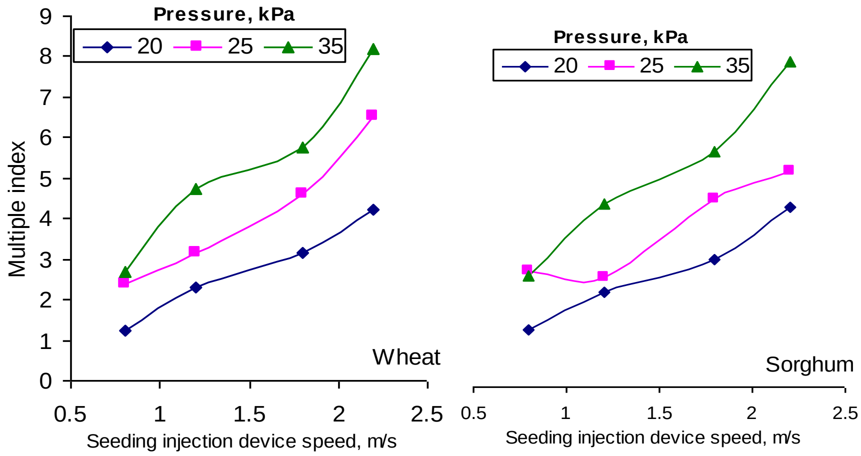

Fig. 12: Effect of injection device speed on the seed multiple index.

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تطوير وحدة تلقيم لآلات الزراعة بالهواء
2- زراعة البذرة بالحقن

زكريا إبراهيم إسماعيل
قسم الهندسة الزراعية – كلية الزراعة – جامعة المنصورة

تعتبر هذه الورقة احدي مخرجات المشروع الممول من وحدة البحوث بجامعة المنصورة لمشروع تطوير وحدة تلقيم الزراعة بالهواء. تم استخدام نظرية دفع الهواء في نقل البذور في لحظه خروجها من الخزان وتوجها إلي الموزع. حيث يعمل هذا الضغط علي نقل البذور بسرعة عالية وبالتالي تخرج من فوهة الجهاز مندفعة (هذا الوضع تم تعريفة علي انه المرحلة الأولي لسرعة البذور) بعد ذلك تندفع البذور لتصطدم بالتربة بالسرعة التي تسمح لها باختراق التربة حيث تم تعريفها من خلال التحليل النظري بالمرحلة الثانية لتغير سرعة البذور. أما المرحلة الأخيرة آو ما يعرف بالوضع الثالث لسرعة البذور وهو من لحظه اختراق سطح التربة إلي وضع استقرار البذور في التربة علي عمق يتوافق وعمق الزراعة بهذا الوضع أمكن استزراع البذور بدون الحاجة إلي حرث أو إزالة لبقيا المحصول الذي سبق استزراعه. لتحقيق هذا الهدف أمكن تصميم وتنفيذ نموذج لوحدة الاستزراع بالحقن من خلال المشروع الممول من وحدة البحوث حيث يم التصنيع داخل ورش القسم بالمنصورة. تم تجربة النموذج المقترح داخل معمل القدرة المتعلق. تم تنفيذ برنامج التجارب علي نوعين من البذور واستخدام فوهتين مختلفتين لفوهة وحدة الحقن لتحقيق سرعات مختلفة عند إسقاط البذور. استخدم معدلات ضغط للهواء مختلفة كما استخدم سرعات تقدم للوحدة مختلفة. أكدت النتائج إمكانية استخدام هذه الوحدة لتحقيق انتظامية عالية في الأراضي التي لم يتم أزاله بقايا المحصول السابق.