

EFFECT OF PHYSICAL AND ENGINEERING PROPERTIES OF SOME CORN SEEDS VARIETIES ON PNEUMATIC MACHINE PERFORMANCE

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ABSTRACT

A series of experiments were carried out during seasons 2005/2007 at Gemmiza Agricultural Research Station, Tanta, El-Gharbia Governorate, Egypt. The objectives of these experiments were to study the effect of some physical and engineering properties of some Egyptian varieties of corn on the performance of the pneumatic drill machine.

The results indicated that, the maximum values of the physical and engineering properties were in case of corn TC 310. But the minimum values were in case of corn ryana. At the same time, the moderate values were in case of corn SC 10. On the other hand, the levels of tractor speed which give the conformity fan air speed with suction air velocity and lowest value of fuel consumption were determined. The results showed that, the fan air speeds were 225, 249 and 247 r.p.m under corn ryana, SC 10 and TC 310, respectively. The fuel consumption rates were 3.4, 3.7 and 3.9 l/h in case of corn ryana, SC 10 and TC 310, respectively.

From the obtained data the study recommended that, the suitable diameter seed plate holes were 7, 7 and 5 mm for corn SC 10, TC 310 and ryana, respectively. Also, the optimum suction air speeds were 12, 14 and 15 m/s for corn ryana, SC 10 and TC 310, respectively. Whereas, the highest percent of seeds holding in seed plate holes were obtained at these speeds. On the other hand, the appropriate operating speed of tractor was 3 km/h.

INTRODUCTION

In Egypt, there is a general tendency to mechanization of agricultural production because the labor costs are expensive, shortage in hand labor and to save the time and efforts.

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There is difference in shape and size in seeds in same varieties, the manual sowing is still traditional in our country. The irregular in shape and differ-

ence in dimensions length “L”, weight “W” and thickness “T” are more important factors which to be indicate low planters efficiency and capacity. For achieving high uniform distribution of seeds in the field by planters, the seeds must be cleaned and graded to meet seed metering devices in the planters. The planters in sowing gave accurately seed spacing specially the inter-row spacing. Also, save in the amount of seeds about 40 - 50 % vs. manual sowing [El-Nakib, 1975].

Ibrahim [1992] mentioned that the physical properties of threshed materials such as size, shape, density, specific gravity and projected area are very important in many problems associated with design or developing of a specific machine.

The farmers usually used more seeds than the recommended rates per unit area. After vigor the farmers distal the more plants to arrival the suitable density of plants for field. On the other hand, 60 % of these seeds are considered as sever seeds losses, but it may be used as human and animal food which influence an increase in sowing crop cost [El-Sahrigi, 1997].

Threshed materials are different from one to another in shape, size, weight, density, moisture content, sphericity and projected area. These parameters are determined factors during the design and performance of seed planters.

Helmy et al. [2002] reported that physical properties of sugar beet seed may be depended on varieties and condition of growth to great extent. Physical properties are useful for specifying the dimensions and design of metering plate of a planter for sugar beet.

Matouk et al. [2004] developed the mathematical relationships relating the changes of the properties with the seed moisture content. The seed principal dimensions, mass of 100 seed and seed projection area are generally increased by increasing seed moisture content. However, both shape-index and coefficient of contact surface area decreased by increasing seed moisture content. ASAE [2005] stated that bulk density

is an important physical property that is required to estimate the volume of storage and pressure that act on storage bin walls.

Nonami and Nelson [2002] conducted a study to enable easy seed and waste separation at head feed combine by measuring the terminal velocity. They found that separation of seeds with primary branches was difficult and straws from a single seed in the tank. The suitable limits of the separating air velocity were from 2.3 to 6.5 m/s.

Santall and Mascheroni [2003] determined the terminal velocity of high oleic sunflower seeds at different levels of moisture content. The results showed that terminal velocity of seeds increased by increasing the moisture content between 2.8 and 5.5 m/s for seeds, between 1.8 and 2.8 m/s for kernel and between 1.1 and 1.9 m/s for hull.

Kaleem et al. [1993] concluded that the effect of the repose angle is very important in determining the inclination angle of the machine hopper tank.

Nimkar and Hattopadhyay [2001] reported that the static friction coefficient varied from [0.344 and 0.625] over different material surfaces, while repose angle from [26.6 and 31 rad.].

The characteristics of seeds are very important in many problems associated with design or development of specific machines. Therefore, agricultural machines were designed on the basis of seeds physical and engineering properties. The main objectives of this work were to study the effect of some physical and engineering properties of some corn varieties on the pneumatic drill machine performance.

MATERIALS AND METHODS

Through the present study some physical, aerodynamic and mechanical properties of some Egyptian corn varieties were investigated. The operating and testing of the prototype unit were conducted at Gemmiza Agricultural Research Station, Tanta, El-Gharbia Governorate, Egypt. Samples of seeds were taken from the field during seasons 2005/2006. The seed varieties were corn, *zea mays L.* varieties hybrid single cross [SC 10], hybrid turubical cross [TC 310] and ryana, *zea mixicana*, ryana teosinta. Random samples of 5 kg from raw seed lots were taken to be examined. The digital instrument was used to measure both friction and

repose angle for the seeds on metal sheet surface with dimensions 14×31.5 cm.

The specifications of the tractor and pneumatic planter which used in this study are indicated in Table 1.

Table 1: The specifications of the tractor and pneumatic planter which used in this study

Tractor		Pneumatic Planter	
Items	Technical specification	Items	Technical specification
Type	Massey Ferguson [MF 230] USA	Model	Gamma 90
Model	AD3.152	Type	Mounted
[PTO] rated horse power, hp	34.53 at 2000 r.p.m	Working width, cm	240
[PTO] operating speed, r.p.m	1789 rpm engine/540	Control	Hydraulic
No. of cylinders	3	Made in	Italy
Idle speed, r.p.m	725–775	No. of rows	4
Maximum speed [No load], r.p.m	2135–2185	Spacing of rows, cm	60
Fuel tank, U.S.	14		
Wheel base	72–3/8		
Length overall [approx.], inches	116		
Width overall [approx.], inches	70		
Front tires, 4 Ply	6–16–F2		
Rear tires, 4 Ply	13.6–28–R1		

- Measuring instruments:

The properties of seeds under study have to be considered for studying their effects on the pneumatic machine performance. These properties such as real and bulk density, moisture content, the terminal velocity, seed drag coefficient, Reynold's number, friction and repose angles, projected area and the suction air velocity.

Digital hydrometer made in Germany, model G-86, with an accuracy of 0.1 % was used for measuring the moisture content in percentage of the studied seeds on wet basis.

The terminal velocity is determined by measuring the air velocity required to suspend a particle in a vertical air stream. The terminal velocity apparatus [Fig.1] consists of an electric blower which discharge air blast into a transparent tapered tube used as a cyclone which is fixed at the outlet side of the blower through an elbow. A screen is fitted at the bottom of the transparent tapered tube of 8×4 cm cross section and a cyclone is fitted at the top of it 15 cm square cross section.

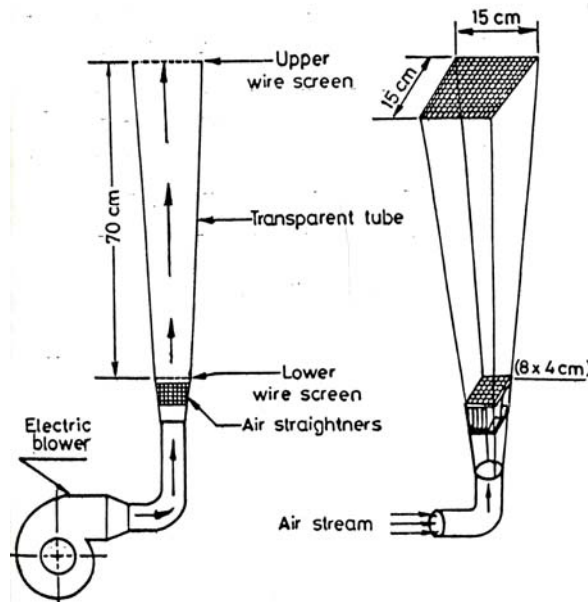


Fig. 1: Terminal velocity apparatus

- Methods:

- Seed real density:

Density is considered to determine the capacity of the seed hopper and conveying unit of the seed cleaner it is expressed as mass per unit volume. Real density was measured for a randomly sample of hundred seeds for each variety of the investigated seeds as follows:

$$D_r = \frac{W}{V_i} \quad [1]$$

Where:

D_r = real density of the seed in g/cm^3 ,

W = mass of the seed in g, and

V_i = real volume of the seed in cm^3 .

Real volume of the seed was measured as the increase in 5 ml sodium nitrate solution, Klenin et al. (1985). Placed in a small graduate cylinder when the seed sample was dropped and immersed in the solution.

- Seed bulk density:

This property was calculated for the investigated seeds varieties by dividing the mass of quantity of each variety by its bulk volume which was calculated by using graduated cylinder as follows:

$$D_b = \frac{W}{v} \quad [2]$$

Where:

D_b = bulk density of the seed in g/cm^3 , and

v = bulk volume of the seed in cm^3 ,

- Seed drag coefficient:

Garrett and Brooker [1965] concerned a technique to evaluate the aerodynamic drag of farm seeds. The drag coefficient commonly is defined as follows:

$$C_d = \frac{2M}{A_p \rho_a V^2} \quad [3]$$

Where:

C_d = drag coefficient in dimensionless,

ρ_a = air density in 1.28 kg/m^3 ,

A_p = projected area in m^2 ,

v_t = terminal velocity in m/s and

M = particle weight in N.

- Reynold's number:

Reynold's number was calculated as follows:

$$N_{\text{Re}} = \frac{\rho_a V_t \sqrt{A_p}}{\mu} \quad [4]$$

Where:

N_{Re} = Reynold's number

v_t = terminal velocity in m/s,

ρ_a = air density in 1.28 kg/m^3 ,

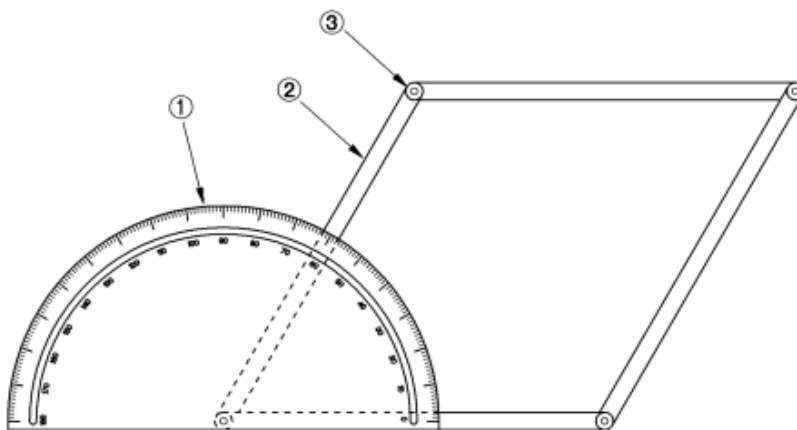
A_p = projected area in mm^2 and

μ = dynamic viscosity of the air in $18 \times 10^{-6} \text{ Pa.s}$.

Laminar flow $N_{Re} < 2100$, turbulent flow $N_{Re} > 4000$ and transitional flow $2000 < N_{Re} < 4000$.

- Meter of repose angle:

This measuring device was used for measuring the angle between the base and the slope of the cone formed due to a free vertical fall of the seed mass as shown in Fig. 2.



1. Wooden protractor 2. Wooden parallelogram 3. Bolts

Fig. 2: Meter repose angle

- Friction coefficient:

Seed friction angle was measured for four masses 50, 100, 150 and 200 gm for each seed variety on one surface galvanized metal sheet, at seed moisture content of 7 to 10 %. The friction coefficient was calculated as follows:

$$\text{Friction coefficient} = \tan \alpha \quad [5]$$

Where:

α = friction angle, deg.

- Seed projected area:

Samples of 100 seed were plotted to measure the projected area using a digital photo camera and computer. The values of projected area of seeds were measured by the order area through auto CAD program with an accuracy of 0.001 mm. The projected area is calculated by using the following equation:

$$\text{Projected area} = \frac{\pi}{4} LW \quad [6]$$

Where:

L = length of seeds in mm, and

W = width of seeds in mm.

- Suction air velocity:

The suction air velocity through the fan inlet pipes was measured at center of each orifice of suction pipes by means of an Anemometer. The measurements were taken through the center of suction pipes section area of the fan inlet pipes. The speed of air suction flow was measured at the center of suction pipes by introducing the probe of Anemometer horizontally to approximately its geometric center. The average of air suction velocity $[V_{av}]$ in the center of suction pipes sectional area of the fan inlet pipes is considered as the average speed of all measurements.

RESULTS AND DISCUSSION

- Seeds physical properties:

- Seed real and bulk density:

The real and bulk densities are considered for determining paging capacity, designing seed hopper dimensions in seed planters, cleaning and grading machines. The values of both of them are indicated in Table 2.

Table 2: Seed real and bulk density for the varieties under study

Variety	Real density, g/cm ³	Bulk density, g/cm ³
Corn ryana	1.061	0.689
Corn SC 10	1.480	0.675
Corn TC 310	1.918	0.716

- Seed projected area:

It is obvious from the data in Table 3, the seed projected area ranges which are indicated by relatively high coefficient of variation values not less than 19.28 and 17.88 % for ryana and not more than 21.15 % and 19.58 % for corn TC 310 at the measurement and calculated projected area respectively. Therefore, the seeds must be graded to obtain uniform seed projected area to facilitate the use of precision seeders and relatively high germination percentage and low seed losses.

Table 3: Calculated seed projected area for the varieties under study

Variety	Range of seed projected area, mm^2	Mean seed projected area, mm^2	C.V, %
Corn ryana	15.39 to 33.47	25.43	17.88
Corn SC 10	28.39 to 96.08	58.69	18.91
Corn TC 310	31.28 to 119.7	77.36	19.58

- Seeds aerodynamic properties:

- Terminal velocity:

The terminal velocity is an important and considered in calculating the air suction needed in the metering devices in pneumatic planters. Fig. 3 illustrates the terminal velocity for crops under study.

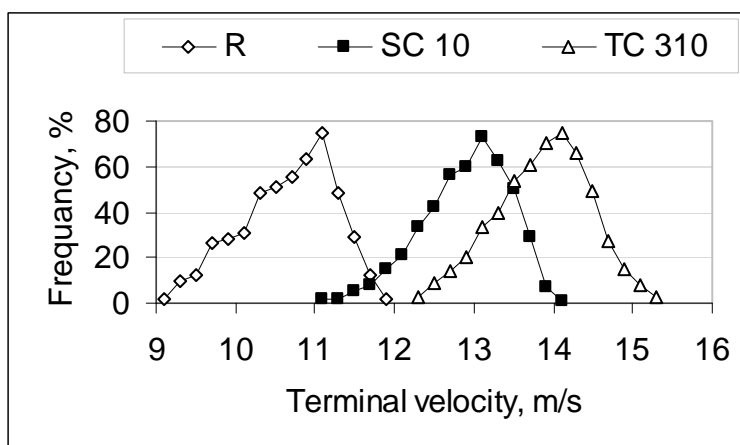


Fig. 3: Distribution curve of seed terminal velocity for corn ryana, SC 10 and TC 310

- Seed drag coefficient:

Drag coefficient plays an important role in separation the foreign, dead, immature, light and broken seed which have different drag coefficient from those of good seeds. The drag coefficient of the seeds calculated according to equation 1. The drag coefficient of the varieties under study can be summarized in Table 4. The data showed that the C.V. values were relatively high for all varieties. Therefore, the seeds must be graded to obtain uniform seed drag coefficient to facilitate the use of precision seeders and relatively high germination percentage and low seed losses.

Table 4: The drag coefficient of the varieties under study

Variety	Rang of drag coefficient	Mean drag coefficient	C.V, %
Corn ryana	0.33 – 4.19	3.11	15.81
Corn SC 10	1.37 – 7.29	4.57	18.22
Corn TC 310	1.42 – 14.47	5.27	20.61

- Reynold's number of seeds:

The effect of particle dimensions on the terminal velocity can best be represented by Reynold's number. The equation 4 was used to calculate the Reynold's number for the seeds. The values of Reynold's number can be summarized in Table 5. The values of the coefficient of variation were relatively high for all varieties. Accordingly, the mean values of Reynold's number obtained are corresponded to transitional flow for corn SC 10 and TC 310 but ryana was laminar flow.

Table 5: Reynold's number of the varieties under study

Variety	Rang of Reynold's number	Mean Reynold's number	C.V, %
Corn ryana	628.87 – 2154.64	1161.84	15.22
Corn SC 10	1754.27 – 5512.61	2676.10	18.97
Corn TC 310	1550.23 – 4611.24	3382.33	19.66

– Drag coefficient and its relation with the Reynold’s number:

The drag coefficient and Reynold’s number values were calculated at equilibrium state. The obtained data for the seed drag coefficient were plotted against the corresponding Reynold’s number. These relationships were found to be negative on plan scale curves as shown in Figs., 4 to 6. The seed drag coefficient decreases with increasing Reynold’s number. These results are supported by those obtained by Sitkei, [1986], who reported that the seed Reynold’s number increased with decreasing drag coefficient.

- Seeds mechanical properties:

- Repose angle and friction coefficient:

The repose angle of seeds depends on the shape and size of seed and the surface conditions. On the other hand, the friction coefficient of seeds is considered for selecting and determining the slopes of the feed hopper of the seed processor and in the design of seed hopper in seed planters. The average values of both repose angle and friction coefficient are indicated in Table 6.

Table 6: The average values of both repose angle and friction coefficient

Variety	Repose angle, rad.	Friction coefficient
Corn ryana	0.37	2.144
Corn SC 10	0.42	2.475
Corn TC 310	0.46	2.605

- Planting machine:

Mechanical planting using pneumatic planter is considered the most important method to achieve uniform distribution of seeds. Recommended speed of planting was chosen in this work. The speeds were for the same gear 3.00, 3.20 and 3.40 km/h.

- Tractor speed and its relation with suction air velocities, fan air speeds and fuel consumption rates:

The relationship between the different suction air velocities, fan air speeds and fuel consumption rates at the first, second and third level of tractor speed are indicated in Table 7. At the first level of tractor speed, the fan air speed and fuel consumption rate increased when suction air velocity increased. The highest value of fan air speed was 247 r.p.m

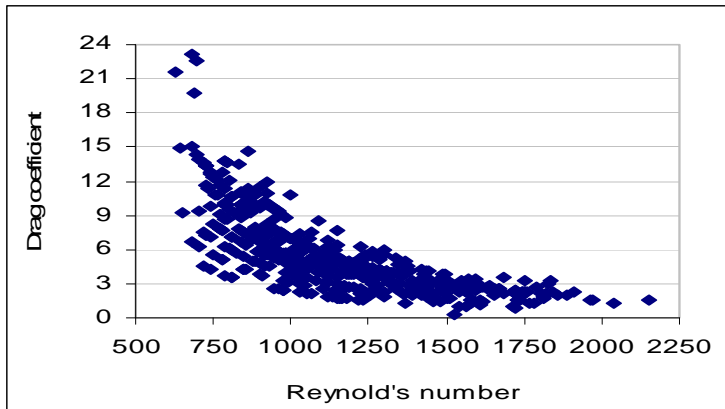


Fig. 4: Drag coefficient, vs. Reynold's number for corn ryana

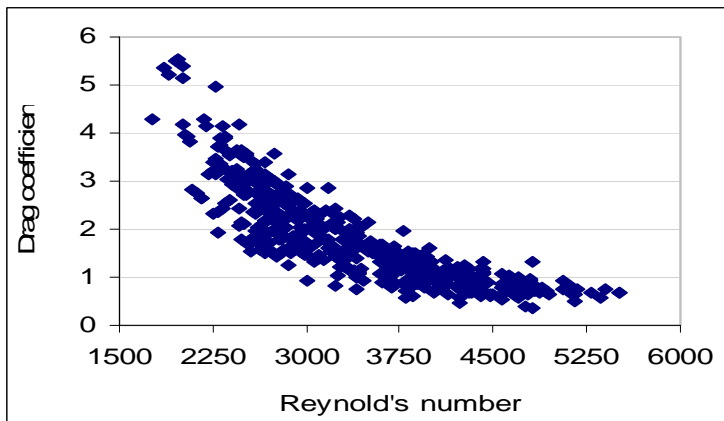


Fig. 5: Drag coefficient, vs. Reynold's number for corn SC 10

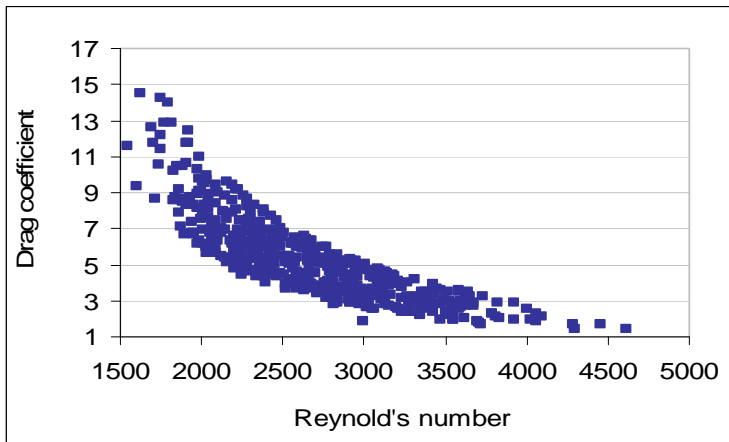


Fig. 6: Drag coefficient, vs. Reynold's number for corn TC 310 under corn TC 310. Meanwhile, the lowest value of fan air speed was 225 r.p.m under corn ryana. At the second level of tractor speed, the fan air speed and fuel consumption rate increased when suction air velocity increased. The highest value of fan air speed was 386 r.p.m under corn TC 310. Meanwhile, the lowest value of fan air speed was 367 r.p.m under ryana. At the third level of tractor speed, the fan air speed and fuel consumption rate increased when suction air velocity increased. The highest value of fan air speed was 975 r.p.m under corn TC 310. Meanwhile, the lowest value of fan air speed was 945 r.p.m under corn ryana. Table

7: The relationship between the different suction air velocities, fan air speeds and fuel consumption rates at the first, second and third levels of tractor speed

Variety	Tractor speed, km/h	Terminal velocity, m/s	Suction air velocity, m/s	Fan air speed, r.p.m	Fuel consumption, l/h
Corn ryana	3.00	11	12	225	3.4
	3.20	11	12	367	4.4
	3.40	11	12	945	5.1
Corn SC 10	3.00	13	14	239	3.7
	3.20	13	14	379	4.5
	3.40	13	14	965	5.2
Corn TC 310	3.00	14	15	247	3.9
	3.20	14	15	386	4.8
	3.40	14	15	975	5.5

CONCLUSION

The results of physical and engineering properties of crop seeds varieties can be summarized as follows:

The seed index values were 67.71, 320.82 and 385.11 g for corn ryana, SC 10 and TC 310, respectively. The real density values were 1.061, 1.480 and 1.918 g/cm³ for corn ryana, SC 10 and TC 310, respectively. The bulk density values were 0.689, 0.678 and 0.716 g/cm³ for corn ryana, SC 10 and TC 310, respectively. The projected area values were

29.46, 73.89 and 82.31 g/cm³ for corn ryana, SC 10 and TC 310, respectively. The angle values were 0.37, 0.42 and 0.46 rad. for corn ryana, SC 10 and TC 310, respectively. The results revealed that the diameter seed plate holes suitable were 5, 7 and 7 mm for corn ryana, SC 10 and TC 310, respectively. Also, the optimum suction air velocities were 12, 14 and 15 m/s for corn ryana, SC 10 and TC 310, respectively. At the same time, the appropriate speed of tractor during planting by using the pneumatic planter was 3 km/h.

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الملخص العربي

تأثير الخواص الطبيعية والهندسية لبعض أصناف بذور الذرة علي أداء آلة الزراعة بشفط الهواء

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أجريت عدة تجارب بمحطة البحوث الزراعية بالجميزة خلال موسمي 2005/2007م بهدف تقدير الخصائص الطبيعية والهندسية (الايروديناميكية والميكانيكية) لبذور أصناف من الذرة وهي الذرة الريانة وذرة هجين فردي 10 والذرة الهجين ثلاثي 310 ودراسة تأثيرها علي أداء آلات الزراعة بشفط الهواء Pneumatic drill. وكانت السرعة الأمامية للجرار ثلاث مستويات (3، 3.20، 3.4 كم/س) وعدد لفات مروحة الهواء كانت ثلاث مستويات أيضاً (225، 239، 247 ل/د). ولتحقيق الهدف من البحث فقد تم التعرف علي أهم العوامل المؤثرة علي معدل التلقيح وكذلك تحديد سرعة تيار الهواء اللازمة لشفط حبوب كل صنف. كذلك تم حساب معدل إستهلاك الوقود في عملية الزراعة. وقد تم تحديد مستوي سرعة التشغيل المناسبة لعملية الزراعة التي تعطي عدد لفات مروحة الهواء المتناسب مع سرعة مروحة الهواء عند معدل استهلاك الوقود وذلك أثناء عملية الزراعة، وخلصت النتائج إلي:

الكثافة الحقيقية كانت 1.061، 1.480، 1.918 جم/سم³ لأصناف الريانة وهجين فردي 10 وهجين ثلاثي 310، علي الترتيب. مؤشر الحبوب seed index (كتلة 1000 حبة) كانت قيمه 67.71، 320.82، 385.11 جم لأصناف الريانة وهجين فردي 10 وهجين ثلاثي 310، علي الترتيب. الكرويه كانت 61، 63، 66 % لأصناف الريانة وهجين فردي 10 وهجين ثلاثي 310، علي الترتيب. سرعة التعليق كانت 11، 13، 14 م/ث لأصناف الريانة وهجين فردي 10 وهجين ثلاثي 310، علي الترتيب. زاوية المكوث كانت 0.37، 0.42، 0.46 رادين لأصناف الريانة وهجين فردي 10 وهجين ثلاثي 310، علي الترتيب. من خلال نتائج الدراسة يمكن التوصية بما يلي:

- في حالة استخدام الذرة الريانة ينبغي أن يكون قطر خلايا قرص التلقيح 5 مم وسرعة شفط الهواء اللازمة 12 م/ث حيث عندها تبلغ نسبة امتلاء قرص التلقيح بالبذور 100%.
- في حالة استخدام الذرة الهجين الفردي 10 ينبغي أن يكون قطر خلايا قرص التلقيح 7 مم وسرعة شفط الهواء اللازمة 14 م/ث حيث عندها تبلغ نسبة امتلاء قرص التلقيح بالبذور 100%.
- في حالة استخدام الذرة هجين ثلاثي 310 ينبغي أن يكون قطر خلايا قرص التلقيح 7 مم وسرعة شفط الهواء اللازمة 15 م/ث حيث عندها تبلغ نسبة امتلاء قرص التلقيح بالبذور 100%.

- أنسب مستوي من سرعة التشغيل الأولي للجرار أعطي أقصى نسبة امتلاء لخلايا قرص التلقيح وأدني معدل استهلاك للوقود كان المستوي الأول من سرعة التشغيل للجرار وقيمته 3 كم/س.

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