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VACUUM PRESSURE DEVICE AS AFFECTED BY SUCTION TUBE CHARACTERISTICS

Ismail, Z. E.*; A. E. Abo El-Magd*; E. B. Elbanna* and Amaal A. Ibrahim**

*** Dept of Agric. Eng. Fac. of Agric. Mansoura Univ.**

****Engineer, Graduate student. Dept of Agric. Eng. Fac. of Agric. Mansoura Univ.**

ABSTRACT

There are numerous types and sizes of air seeders and planters, some of the designs and concepts used for vacuum air are recognized. Planting using vacuum air systems faces multiple problems. One of the most important is optimum vacuum pressure through delivery air tube from outlet gate of vacuum pump to grain picking orifices at circumference of feeding disc. From this standpoint this research aims to identify the lowest vacuum levels that recognized best captures of corn grains. To perform this study, a similar model of six rows vacuum planter with six delivery tube lines different in length was constructed in Farm Machinery Laboratory Research (Ismail, 2004) as part of outcomes from a project financed by Researching Unit of Mansoura University. The response surface program of Minitab 17 was used to identify relationship between vacuum pressure (kPa) and each of blower speed (FnS, rpm), vacuum measuring location far from outlet of blower orifice "LVT" and three different of air delivery tube length "TL". The maximum vacuum pressure (4.19 kPa) was recorded at blower speed of 657.6 rpm at distance from the blower outlet orifice "LVT" of 0.27m. Also, it can be stated that, increasing the "LVT" distance from the blower outlet orifice, or decreasing the "FnS" speed lead to demolish the "VPm" values. Moreover, the effect of height of "FnS" parameter was more than that the effect of "LVT" parameter. Also by increasing the location of measuring points far from outlet blower the "VPm" decreased under all different variables. The decreasing rates were found about 0.75; 0.77 and 0.68 times as increasing “LVT” from 0.14- 1.5m; from 0.28-2.0m and from 0.27 to 3.0m respectively at blower speed of 310.4rpm.

INTRODUCTION

In Egypt the corn crop is considered as one of the major crops. The total cultivated area of corn crop is about 1482 thousand feddans produced about 5027 thousand ton (Ministry of Agriculture and Land Reclamation, 2012). The corn grain usually planted manually but it can be planting using the machine. Then, now a days it’s very important to use the precision machines to plant the most crops. Several successful pneumatic seeders for large agricultural grains are commercially available, and they can be used to plant the corn grain. Many researchers indicated that the drop in the pressure at the end of the planting tube using the pneumatic planter is the major factors affecting grain distribution. In the field, Shafii and Holmes, (1990) developed two mathematical models for predicting the pressure distribution and forces exerting on the grain during holding. Unfortunately they used spherical balls of various diameters to represent grains. Results indicated that, the model derived from stagnation point flow and boundary-layer theory accurately predicted the pressure and forces on the grain for the 1.59 mm orifice over the range of corn-grain clearances yielding high retaining forces. Also, the terminal velocity of grains in the air stream has to be known prior to the design of vacuum type precision seeders and these values were found to be $7.8 ms^{-1}$ for cotton (Tabak and Wolf, 1998) and $11.8 ms^{-1}$ for corn (Gorial and O'Callaghan, 1990). Karayel *et al.* (2004) determine the optimum vacuum pressure of a precision vacuum seeder. They found that the optimum vacuum pressure was determined as 4.0 kPa for corn, 3.0 kPa for cotton and soya bean; 2.5 kPa for watermelon and cucumber; 2.0 kPa for sugar beet; and 1.5 kPa for onion grains. The vacuum pressure was predicted by mathematical models. According to the results, the final model could satisfactorily describe the vacuum pressure of the precision vacuum seeder with a chi-square of 2.51×10^{-3}, root mean square error of 2.74×10^{-2} and modeling efficiency of 0.99.

Singh *et al.* (2005) investigated the performance of the seed-metering device of a pneumatic planter was investigated under laboratory and field conditions to optimize the design and operating parameters for cotton seed planting. The effect of operational speed of the disc, vacuum pressure and shape of the entry of seed hole were evaluated by examining the mean seed spacing, precision in spacing (coefficient of variation), miss index, multiple index, and highest quality of feed index. For picking single seeds, the planter disc had a seed hole of 2.5 mm in diameter. The entry cone angle of the hole was varied from 90 to 150°, the speed varied from 0.29 to 0.69 m/s, and the vacuum pressure varied from 1.0 to 2.5 kPa. The metering system of the planter was set to place the seeds at 250 mm spacing. There observed that the planter disc with a 120° entry cone angle gave superior performance at all speeds and operating pressures. However, there was no conclusive statistical evidence to identify a single value of disc speed or vacuum pressure. Lower miss indices were observed at higher pressures and lower speeds, and lower multiple indices at lower pressure and higher speeds. The metering system with a speed of 0.42 m/s, and a vacuum pressure of 2.0 kPa produced superior results with a feed index of 94.7 % and a coefficient of variation in spacing of 8.6 %, recording a mean seed spacing of 251 mm.

Afife *el al.* (2009) carried out experiments under laboratory conditions on onion seed properties. Engineering calculations were performed for estimating the vacuum characteristics and also for calculating the hole geometry of seed plate. On the other hand, soil bin tests were carried out to verify the accuracy of developed model at various levels of blower (vacuum pump) speeds using three seed plates with different hole diameters. While, Deng *et al.* (2010) focused on the picking-seed process of pneumatic precision metering device for rapeseed, and mathematical models were proposed from two special points: the contact force and air flow disturbance of the sucking-seed process. Some optimal principles were obtained by minimizing the contact force and the disturbance error, and these principles could be used to improve the effect of the rapeseed metering device. The ideal used in this paper could also be applied to vacuum metering devices for other seeds. It is worthwhile to point out that the results presented in this research is only generalized conclusions for the selection of structure and operating parameters of a metering device, and its applications are based on the initial parameter intervals associated with an acceptable performance of the metering device.

From the point of precision seeding technique and for meeting agro-technical needs, corn grains should be sown precisely without causing doubling and missing during field operations. Doubling and missing in the row are unwanted since doubling affects yield and dry matter while missing causes a reduction in yield (Rintelen, 1971 and Demmel et al., 2000). The relationship between catching grains forces and each of blower speed, delivery tube lengths and location of tube bending were not investigated.

Therefore, this investigation aims to identify the lowest vacuum levels that recognized best captures of corn grain and also to evaluate vacuum pressure (kPa) relative to each of blower speed (FnS, rpm), vacuum measuring location far from outlet of blower orifice “LVT” and three different of air delivery tube length “TL”.

MATERIALS AND METHODS

The experiments were carried out at Farm Power and Machines Laboratory Research that constructed by Ismail (2004) as part of outcomes from a project financed by Researching Unit of Mansoura University. To achieve the experimental aim, a similar model of two groups of tubes each of 3 tubes were equipped at both left and right sides of the blower, in each group tubes length of 1.5, 2.0 and 3.0 m from the shorter to the tallest tube were equipped as shown Figs.(1 and 2)

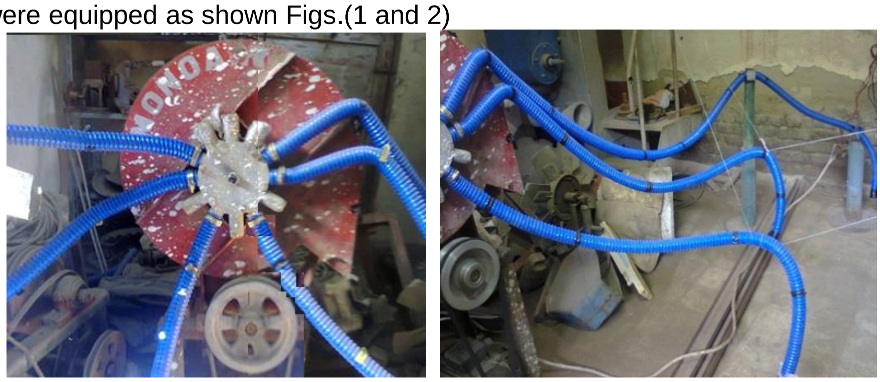
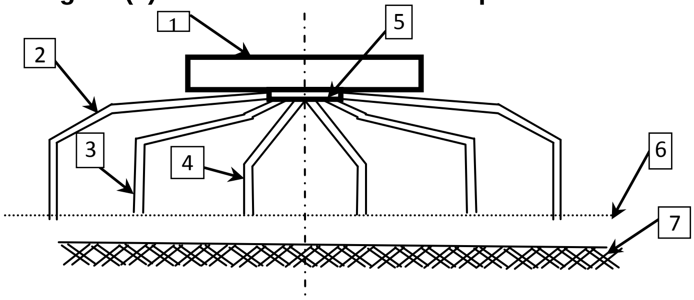


Figure (1): Vacuum air blower in experimental lab



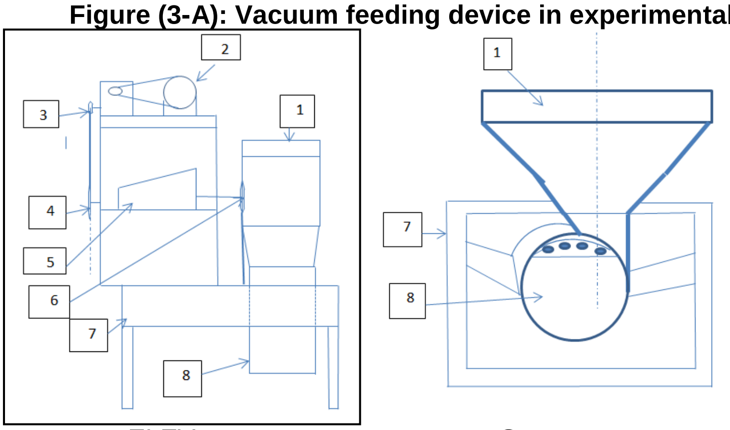
1- Blower, 2- Air delivery tube 3.0m, 3- Air delivery tube 2.0m,
4- Air delivery tube 1.5m, 5- Suction holes of the blower,
6- End of air delivery tube from the ground, 7-Ground surfce

Figure (2): The blower with delivery tube section.

The air vacuum blower with outer cover diameter of 600 mm and 160 mm air inlet diameter was used to supply vacuum for corn planter. It was set on a rectangular frame made from iron steel. Inside this frame an electrical motor was fixer. The specification of electrical motor is three phase with 1.47 kW at 1480 rpm. The motion is transmitted from electric motor to blower by means of pulleys and belts to produce 1 to 10 ratios.

The six air delivery tubes were distributed to simulate the normal situation of the real vacuum corn planter. The average outer diameter of tube was 40±2mm inner diameters of 38± 0.2mm. Also, the same air tube curvature was simulating rogue to found in position during Gaspardo planter operating. At the curvature of air tubes, vacuum pressure values were measured under three replications. The precision vacuum pressures in air delivery tubes were measured under four levels of vacuum values that obtained from four levels of blower speeds (FnS) were 310.4; 434.5; 541.8; and 657.6, rpm. The feeding device was fixed above the soil bin as shown in figures (3-A) and (3-B). It is included feeding disc with a diameter of 250mm and 32 circular holes distributed on outer disc circumference each of 5mm diameter.

Figure (3-A): Vacuum feeding device in experimental lab



ELEV. S.v.

1- Hopper, 2- Motor, 3- Gear16 teeth, 4-Gear48 teeth, 5- Gear box, 6- Gear 20 teeth, 7- Frame, 8- Feeding disc.

Figure (3-B): the layout precision vacuum prototype.

The pressure gauge manometer with a sensitivity of 0.1 kPa was used to measure vacuum air pressure for all points under experiment. At 0.27, 0.58, 1.12, 1.50, 1.91, 2.00, 2.21, 2.81 and 3.00 m far from outlet of blower orifice.

The variables considered in the present study were 3100.4, 4340.5, 5410.8 and 6570.6; rpm blower speed; 1.5, 2.5, 3.8 and 4.8, kPa vacuum pressure and three different air delivery tube lengths “TL” (1.5, 2.0 and 3.0m). Response Surface Methodology was applied to indicate and was conduct sensing central composite design (CCD) of Minitab 17.

The results obtained from the experiments based on (CCD) were used to develop mathematical functions in quadratic and forms for corn grains. From these mathematical functions the optimum level for each variable was obtained in the study.

RESULTS AND DISCUSSION

The planting vacuum systems are usually more efficient that the common planting methods. Therefore, the vacuum methods should design in such a manner to ensure adequate and uniform grains and to minimize the grains deviations. The primary experimental and many researchers indicated that the main factor affecting the quality of vacuum mechanism is the vacuum pressure values a long air delivery vacuum tube.

Vacuum pressure via blower speed

To exam the effect of “FnS” on the “VPm”, the experimental lab was conducted as primary tested as shown in figure (4). The regression equation describes the relationship between the response (VPm) and predictor variables by indicators of “CI” and “PI” at 95% respectively. The dependence of vacuum pressure (VPm) on blower speed (FnS) was further studied using multiple regression analysis. It was found that vacuum pressure (VPm) was depended strongly upon the blower speed (FnS). The regression equation estimated to be:

$$VPm = -1.665 + 0.0087\ FnS - 0.000001\ FnS^2$$

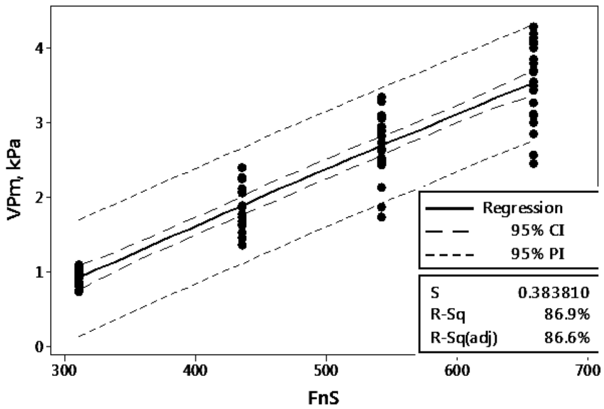


Figure (4): Fitted line plot for VPm via FnS

The residual plots for “VPm” are presented in figure (5). As the number of observations decreases, the probability plot may show even greater variation and nonlinearity. Use the normal probability plot and goodness-of-fit tests to assess the normality of residuals in small data sets. Tail falls slightly away from the line. No evidence of non-normality, skewness, outliers, or unidentified variables exists.

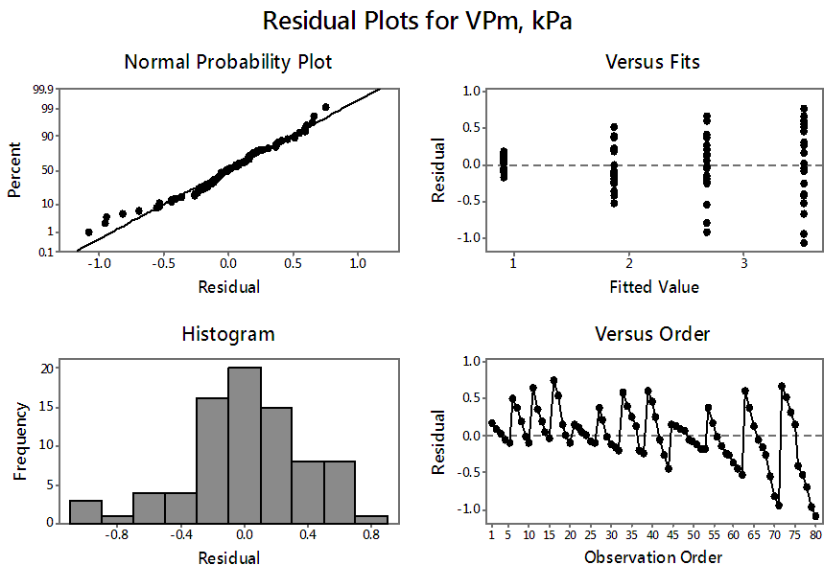


Figure (5): Residual plots for VPm

In other words it could be stated, that to obtain the desired planter vacuum pressure (2.0 kPa), it was necessary to increase the maximum available blower speed (4000 rpm) of the tested pneumatic unit by about (1.25 times). The results showed that the planter is necessary to increase the maximum available air speed to reach to a level of 5000 rpm.

Vacuum pressure via air delivery tube length (TL, m)

Figure (6) illustrates the relationship between the values of vacuum pressure and the three lengths air delivery tube (1.5; 2.0 and 3.0 m). Generally, by increasing the tube length from 1.5 to 3.0m vacuum pressure was inversely reducing by about 0.09 times. The fitted line plot for above response data explained by the predictors and the amount of variation per measuring “VPm” through different air delivery tube length was as follows:-

$$\text{VPm, kPa} = 2.82749 * \exp(-0.0983353 * \text{'TL, m'})$$

The analysis of variance for response relation (VPm) with in-dependent variables indicated no significant effect. Figure (7) indicates residual plots for VPm relative to TL. It includes the following:-

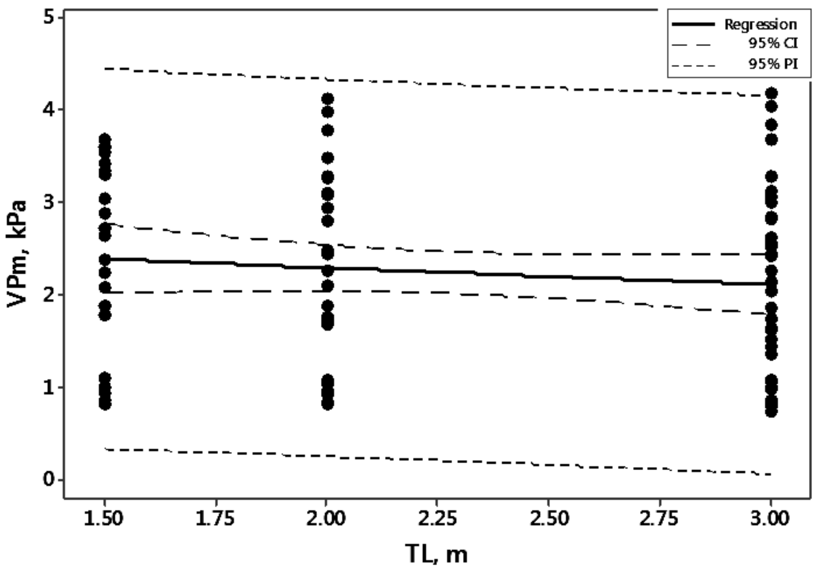


Figure (6): The fitted line plot for VPm via TL

a- Normal probability plot for residual equation data as percentage (figure 7-a) relative to 45^0 lines. All most data lie on inclination line.

b- The frequency plot for residuals histogram (figure 7-b) indicates that no-clear trend was not found for data and all the data nearly are equals.

c- Versus fitted value for the above relationship illustrates in figure (7-C) indicated that residuals values lie between +2 and -2.

d- Versus order value for the above relationship illustrates in figure (7-d) indicated that there is a harmony repeat for data.

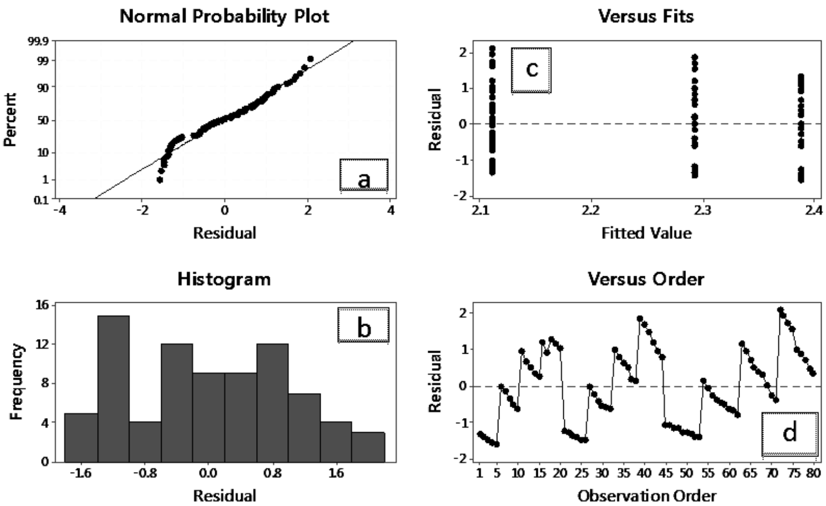


Figure (7): Residual plots for VPm via TL

Vacuum pressure via location of air delivery tube length

Figure (8) illustrates the relationship between the values of vacuum pressure (VPm) and different locations in air vacuum delivery tube (LVT). Generally, by increasing the location of measuring points far from outlet blower the "VPm" decreased under all different variables. The decreasing rates were found by about 0.75; 0.77 and 0.68 times at increasing "LVT" from 0.14- 1.5m; from 0.28-2.0m and from 0.27 to 3.0m respectively at blower speed of 310.4rpm. The fitted line plot for above response data explained by the predictors and the amount of variation per measuring "VPm" through different "LVT" was as follows:-

$$VPm,\ kPa = 2.85119 * \exp(-0.184426 * LVT)$$

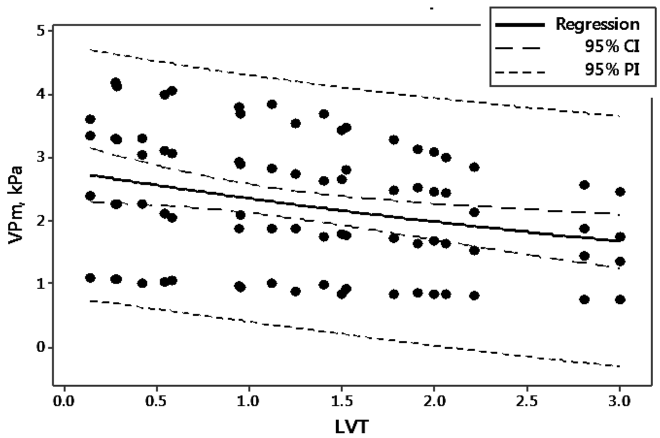


Figure (8): The fitted line plot for VPm via LVT

The analysis of variance for response relation (VPm) with un-dependent variables (LVT) indicated no significant effect. Figure (9) indicates residual plots for VPm relative to LVT. It includes the following:-

a- Normal probability plot for residual equation data as percentage (figure 9-a) relative to 45^0 lines. A little of data lie far form inclination line.
b- The frequency plot for residuals histogram (figure 9-b) indicates that no-clear trend was not found for data.
c- Versus fitted value for the above relationship illustrates in figure (9-C) indicated that residuals values lie between +2 and -2.
d- Versus order value for the above relationship illustrates in figure (9-d) indicated that there is a harmony repeat for data.

ACKNOWLEDGEMENTS

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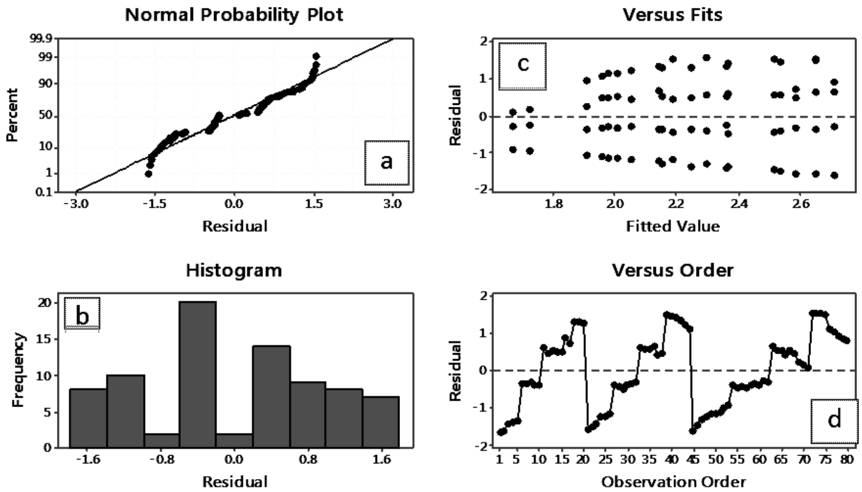

Figure (9): Residual plots for VPm via LVT

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تأثير جهاز شفط الهواء على مواصفات أنبوب الشفط

زكريا إبراهيم إسماعيل،الشحات بركات البنا،على السيد أبو المجد و أمال عبد الناصر أحمد إبراهيم

*** قسم الهندسة الزراعية – كلية الزراعة – جامعة المنصورة**

**** مهندسة وطالبة دراسات عليا قسم الهندسة الزراعية – كلية الزراعة – جامعة المنصورة**

إن الزراعة بإستخدام الهواء تواجه مشكلات متعددة أهمها تذبذب الضغط خلال مراحل تلقيم البذور بداية من منطقة دفع الهواء وحتى نهاية أنبوبة شفط الهواء خاصة مع إختلاف أطوال الأنابيب فى آلات الزراعة متعددة الوحدات ومن هذا المنطلق يهدف هذا البحث إلى تحديد أفضل قوى شفط للهواء تعمل على إتزان الضغط عند نهايات أنابيب شفط الهواء (قرب قرص التلقيم). ولتنفيذ هذه الدراسة تم تصميم نموذج مماثل لآلة زراعة بشفط الهواء ذو ستة خطوط بأطوال أنابيب هواء 1.5، 2.0، 3.0 متر فى معمل الأبحاث المقام بقسم الهندسة الزراعية والممول من وحدة البحوث بجامعة المنصورة سنة (2004) يمكن خلالها قياس قيم فواقد الشفط عند نقاط مختلفة على أنابيب شفط الهواء وذلك عند سرعات مروحة (3100.0، 4340.5، 5410.8، 6570.6 لفة/دقيقة) – ضغط هواء 1.5، 2.5، 3.8، 4.8 كيلوباسكال. وتم قياس ضغط الهواء عند مسافات 0.27، 0.58، 1.12، 1.40، 1.91، 2.06، 2.21، 2.81، 3.00 متر من نقطة التثبيت على المروحة (البلاور). وقد تم إستخدام برنامج (Minitab 17) لتحليل النتائج بنظام الإستجابة السطحية. ووجد أن أقصى ضغط لشفط الهواء 4.19 كيلوباسكال سجل عند سرعة مروحة 6570.6 لفة/دقيقة، وعلى بعد 0.27 متر من مروحة شفط الهواء، كما وجد أن معدل الإنخفاض فى الضغط كان 0.75، 0.77، 0.68 مرة عند تغير نقطة القياس داخل الأنابيب من 0.14 – 1.5، 0.28 – 2.0، 0.27 – 3.0 متر وذلك عند سرعة مروحة الشفط 3100.4 لفة/ دقيقة.

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