

Laboratory and Field Investigation Comparison for Seed Distribution Accuracy of a Multi-Rows Pneumatic Plate Metering Device

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ABSTRACT---*The aim of the study was to examine and compare the impact of laboratory and field trials on kernels distribution accuracy of a multi-rows pneumatic plate metering device. The effect of the two methods was verified at 15 and 20 r/min plate rotating speed integrated with most favorable values of 1.2 and 1.4 kPa vacuum pressures, respectively. A constant forward velocity of 2.7 km/hr was utilized for belt test and seed planter. Results exposed that vacuum amounts utilized with mentioned speeds were adequate for achieving precise seeding. Under both methods and speeds, laboratory attempts were found to be better in quality index than field trials with some propensity of 15 r/min to be superior. The lowest quality index obtained was 87.3% by field test, while worst miss and multiple indexes were 5.36% and 8.06%, respectively. Rows consistency CV was beneath 1.5% and the stability not surpassed 7.1%. Due to a set of factors confronting seed preciseness in the field, results concluded that more endeavors are robustly required to control such factors.*

Keywords--- Multi-rows pneumatic plate, laboratory and field test, seed preciseness

1. INTRODUCTION

Precise seeding as a pattern of seed distribution process had been instituted in early 1940s (Yasir et al., 2012). The process is defined as a positioning of individual grains in an appropriate spacing. Precision seeding generates a set of advantages; it minimize extreme seeds usage by precisely distributing, reduce seed rolling in turns it give exact seed number per length, and allow carrying out the following field operations with lower costs (Domier, 1991). Moreover, the process provides an optimal stand gaps thus it diminishes their competition (Heege, 1993).

The most vital constituent in seeding equipment is the metering device (Yang et al., 2016). A number of metering systems are currently used in precise seeding (Guler, 2005; Boydas and Turgut, 2007). These devices are operated either mechanically or pneumatically due to their metering principle. Pneumatic actuating have some advantages over mechanical type; they are better in seed pick-up, accurate in seed rate, provide lower grain damage (Guozhong et al., 2015; Liu et al., 2016; Searle et al., 2008). Because of the nature and characteristics of numerous seeds, their metering operation by mechanical devices cause some injuries and close metering holes (Jiajia et al., 2014; Li et al., 2012). This situation guide scholars to employ pneumatic

types either of positive or negative pressure, or even combination of the two (Cong *et al.*, 2014a; Li *et al.*, 2014; Li *et al.*, 2015; Wang *et al.*, 2018).

A variety of studies were formerly executed to study the performance of precision planters, whether they were laboratory or field trials. Karaye *et al.* (2004) instituted a mathematical model depending upon cereals physical properties to realize the optimal vacuum magnitude of seeding equipment. Grain suction capability by a pressurized metering system was studied to verify plate velocity, hole number, diameter and radius of pressure orifice (Deng *et al.*, 2010; Ibrahim *et al.*, 2018). Singh *et al.* (2005) studied the impact of plate angular velocity, vacuum pressure and the entrance shape of air nozzle on cottonseed distribution and instituted the current precision indices. Yazgi and Degirmencioglu (2007) made use of Response Surface Methodology (RSM) to look for a seed planter spacing outcomes. Panning *et al.* (2000) applied an optoelectronic sensor system to examine distributed kernel locations. Consequently, the stability of distances was portrayed by utilizing coefficient of precision. Additionally, the technique was employed to find out time intervals between successive dropping grains, and front and back locations (Lan *et al.*, 1999; Kocher *et al.*, 1998). Karaye *et al.* (2006) involved high-speed camera technique to detect fallen seeds velocities and distribution accuracy. Results of the camera were matched to that of greased-belt. Several scholars attempted belt test bench integrated with a computerized camera technique for grain observing to look for distribution performance. Results appeared there was no injured kernels while their precision was clearly influenced by operating speed and pressure level (Qingxi *et al.*, 2009; Onal and Onal, 2009; Elebaid and Liao, 2018). Zhan *et al.* (2010) employed Computational Fluid Dynamics (CFD) to compute and analyze forces acting on dropping seeds, accordingly seed movement and their trajectories have been illuminated by using a series of numerical equations (Zhan *et al.*, 2010).

One of the lately applied pressurized disk metering devices restrictions is their deficiencies to perform multi-rows simultaneously (Cong *et al.*, 2014b; Elebaid and Liao, 2018). They generally employing a sole plate equipped with a single row of holes around its center and fit to a separate unit of the planter. Thus, the situation results in heavier equipment, complicated seeder's transmission and pressure systems, and more power will be needed; so they jointly bring unnecessary costs. However, the recently utilized multi-rows pneumatic plate was previously constructed to remove such problems by eliminating planter's separate metering units and that to make simple machine with easier operation and avert additional cost. The prototype had been formerly investigated under a set of disk velocities coupled with vacuum pressure influence. Due to some variations in rows pick-up, some competent methods and techniques have been successfully tried as an attempt for realizing same rows seed picking. A curved-edge seed ejector was one of the most preferable means for this purpose. In recent study, grain metering operation under laboratory and field trials were examined by employing curved-edge ejector aiming at realizing distribution performance under different test conditions.

The core purpose of the work was to look into seed spacing accuracy of laboratory and field tests and compare their results according to precision indices. The work was carried out to inspect:

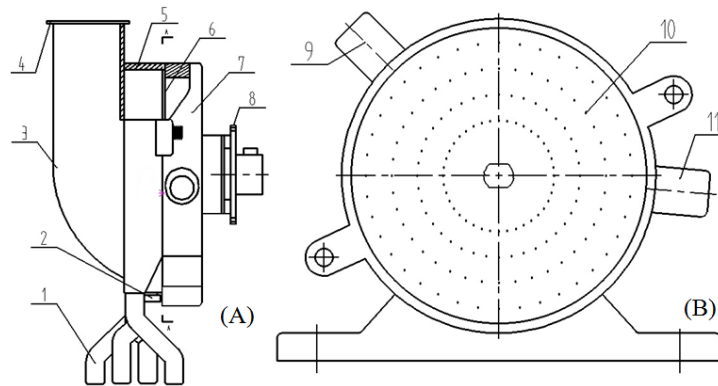
- seed precision performance under two plate rotating speeds and constant belt and planter forward speed,
- test conditions in the laboratory and field experiments,
- Rows' seed distribution stability and consistency under the two methods,

2. MATERIALS AND METHODS

2.1 Structure and working principle of the prototype

The prototype employing a pressurized vertical plate with four-rows as a metering element formerly developed for sowing small seed-types. A side part of the disk connects to negative pressure source at kernel picking and retaining phase, and positive pressure at dropping area, while the other face constitute seed supply area and discharge tubes. Figure 1(a) present the constructional elements of the prototype, while figure 1(b) exhibits the metering plate mounted to pressure chamber. The air chamber was made up with two cavities; one receives vacuum for seed picking and holding and the other convey positive pressure for dropping.

The metering plate is equipped with four rows of holes around its center of rotation (fig. 1b) aiming at performing four planting rows at once. Each row was made in form of 40 round metering nozzles punched with 1.2 mm each with 14 mm as a gap between adjacent two rows. According to the test and investigation, 1.2 mm nozzle diameter was found to be appropriate for smooth picking of tested seeds, and it was confirmed also by (Cong *et al.*, 2014a; Li *et al.*, 2015).

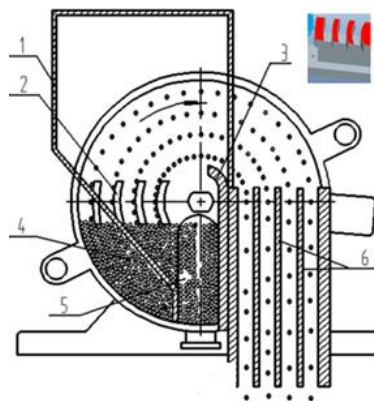


1. Seed tube; 2. Seed discharge nut; 3. Seed box; 4. Seed box cover; 5. Plate cover; 6. Metering plate; 7. Pressure chamber; 8. Driving sprocket; 9. Vacuum inlet; 10. Metering nozzles; 11. Positive pressure inlet.

Figure1(a): a schematic diagram of the multi-rows pneumatic plate metering device; (b) showing the metering plate on its groove in pressure cavity.

The prototype employed a cured-edge device as illustrated in figure 2 for multiple seed ejecting. The device is exactly a rigid plastic element with four curved-edges constructed to be in the same arcs and distance between neighboring holes of the rows (14 mm). The edges were made in such a shape as to avoid single seed obstruction and allow smooth contact with multiples. The device could be adjusted where the edges are near enough to make a little contact but remove multiples.

Grain metering operation by using curved-edge device is simply occurring as shown in Fig. 2. A transparent cut view of the metering device shield showing how grain metering operation takes place. Seeds from gathering section are sucked by vacuum force; sometimes a group of seeds is picked by air nozzles. As cereals pass beside curved-edge device they touch the edge which drive out multiples and may maintain only single seed. Thereafter, seeds are detachedly dropped down at release point by means of separators.



1. Seed box; 2. Curved-edge singling device; 3. Seed barrier; 4. Seeds area; 5. Seed flow opening; 6. Separators

Figure 2: Transparent cut of metering plate shield viewing curved-edge device in metering operation

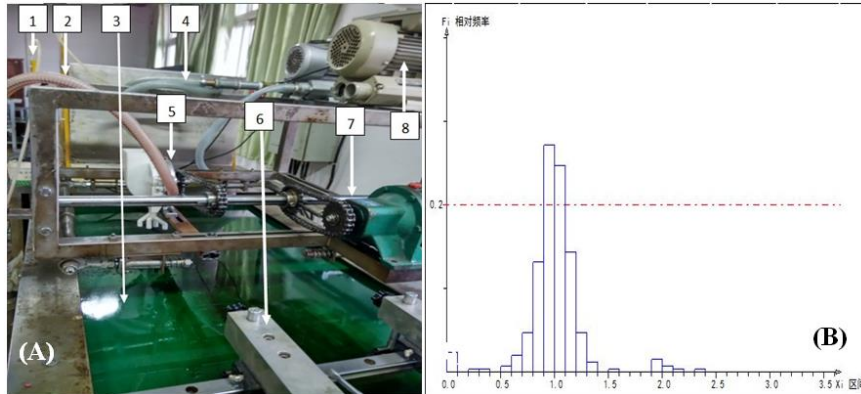
2.2 Test methods

2.2.1 Laboratory seed precision

In this test, the prototype device was placed above greased belt test and driven by the system motor as viewed in figure 3 A. The device was investigated at two operational velocities, namely; 15 and 20r/min integrated with their most appropriate vacuum magnitudes of -1.2 and -1.4 Kpa, respectively. The belt was actuated at a steady speed of 2.7 km/hr. Released seeds drop down onto the oily surface of the sticky belt. Afterwards, dropped cereals pass beneath the covering area of monitoring camera system. As result, a computer software system incorporated with belt data compute seed spacing employing formula (1) and provide test results in graph forms as in (Fig. 3 B).

$$\text{Theoretical spacing (mm)} = \frac{\text{belt speed (km.h}^{-1}) \times 10^6}{60 \times \text{rotating speed (rpm)} \times \text{number of holes}} \quad (1)$$

Each row had been independently investigated, while seeds drop from other rows were collected by a special device for the purpose. Under mentioned plate velocities, the test was repeated five times and the mean value for each index had been acquired.



1. U-tube manometer; 2. Positive pressure line; 3. Greased belt; 4. Vacuum pressure line; 5. Metering device; 6. Oil supply device; 7. Variable speed motor; 8. Air pump

Figure 3: (A) Sticky belt test for seed precision; (B) Seed distribution pattern and graphical layout.

Precision indices can be established as reported by Singh *et al.* (2005 as follows:

Miss Index: is defined as a percentage of grain distance that bigger than 1.5 times theoretical spacing (S) which expressed by formula (2):

$$I_{Miss} = \frac{n_1}{N} \times 100 \quad (2)$$

where, n_1 : is the spacing number greater than 1.5 S ; N : is the total number of measured spacings.

Multiple Index: is described by the ratio of kernels gaps lower than or equal to the half theoretical spacings (S) and elucidated by formula (3):

$$I_{Mult} = \frac{n_2}{N} \times 100 \quad (3)$$

where, n_2 : is the number of spacings $\leq 0.5 S$.

Quality of feed index (QFI): defined as a percentage of grain spacing more than half but not exceed 1.5 times theoretical (S), it clarified by simple formula (4):

$$I_{QF} = 100 - (I_{Miss} + I_{Mult}) \quad (4)$$

3.2.2 Field seed distribution investigation

Before starting field experiments, initial tests and seeder set up have been made at the field borders for verifying seed picking while equipment was stationary. Vacuum was adjusted to values sufficient for seed sucking without missing by providing a suitable PTO speed and using pressure flow valve. It was set at -1.2 and -1.4 kPa as to match plate speed of 15 and 20 r/min, respectively. Positive pressure was relieved and only 0.2 kPa was exploited for seed release which resulted in no overlapping with negative pressure effect. Seed planter (Fig.4) was operated at 2.7 km/hr under both disk rotating speeds. Data was collected after seedlings emergence by measuring distances between plants within the rows. One hundred spacing measurements have been made within each row. Data was independently attained for each row as to avoid results mixing. Thereafter, results was categorized into three groups (miss, multiple and quality index) according to the theoretical seed spacing obtained by formula 1, and then the percentage of each index was computed using equations 2, 3 and 4.



Figure 4: Two copies of the prototype mounted to a seed planter for field experiment.

3. RESULTS AND DISCUSSION

3.1 Seed distribution results comparison of the two methods

The influence of laboratory and field tests on seed distribution process was demonstrated relying on quality of feed index (QFI) of the rows and their consistency CV. Results procured by the two methods were presented in table 1 to clarify the variability between them, and at the same time between the rows. The table exhibits the outcomes of the methods at two plate velocities incorporated with their optimal matching vacuum levels. It was found that -1.2 and -1.4 kPa vacuum magnitudes were perfectly matched the speeds of 15 and 20 r/min., respectively. Positive pressure had been gradually applied for seed releasing as to avoid its negative effect on seed picking, whereas 0.2 kPa was found to be appropriate for the purpose. It could be perceived from the table that laboratory test was superior to field experiment in rows' quality of feed index values under both inspected velocities, where it generated higher quality index of 91.34% and 91.42% at 15 and 20 r/min, respectively. This refers mainly to the controllable operational factors of laboratory trials. However, it's difficult to overcome field test obstructions such as pressure instability, skip or multiple seeds, and seeds dropping trajectory and locations. Multiple and miss seeds are recurrently occurring during metering process. Such results are agreed with those acquired by some researchers who reported that kernel pick-up is mostly varied at pressure levels and metering element speeds (Liao *et al.*, 2009; Yazgi and Degirmencioglu, 2014). Furthermore, field operation results may also affected by seed vitality and germination ratio. The highest mean quality index obtained by the rows at both velocities was not over 91.42%, and the poorest was around 87.32%, while the highest rows consistency CV was not surpassed 1.5%. Seeds dropping trajectories and locations are generally influencing by dropping height, design of conveying tubes, machine vibration, and soil surface conditions. Results of field attempts disclose that grain distribution might be confronted by a set of factors, which could be returned to all or some of above mentioned factors. The table also showed that field experiment attained the lowest results through row 1 at both speeds. This may refer largely to multiple seed occurrence through this row level which produced slightly higher multiple index and relatively low quality index. Some results of distributed seeds by either laboratory tests or field attempts are viewed in figure 5 (A and B).

Table 1. Results of the two methods on seed quality of feed index

RS*NP (rpm*kPa)	Test Methods	Rows Quality Feed Index, %				Mean, %	SD	CV, %
		R1	R2	R3	R4			
15*1.2	Lab. Test	91.13	91.32	91.34	90.52	91.08	0.385	0.423
	Field Experim.	89.55	90.12	89.61	89.72	89.75	0.258	0.288
20*1.4	Lab. Test	90.61	91.42	90.67	91.12	90.97	0.384	0.403
	Field Experim.	87.32	90.10	88.90	89.81	89.81	1.253	1.408

RS*NP: Combined Rotating Speed (RS) and Negative Pressure (NP); SD: Standard Deviation; CV: Coefficient of Variance.

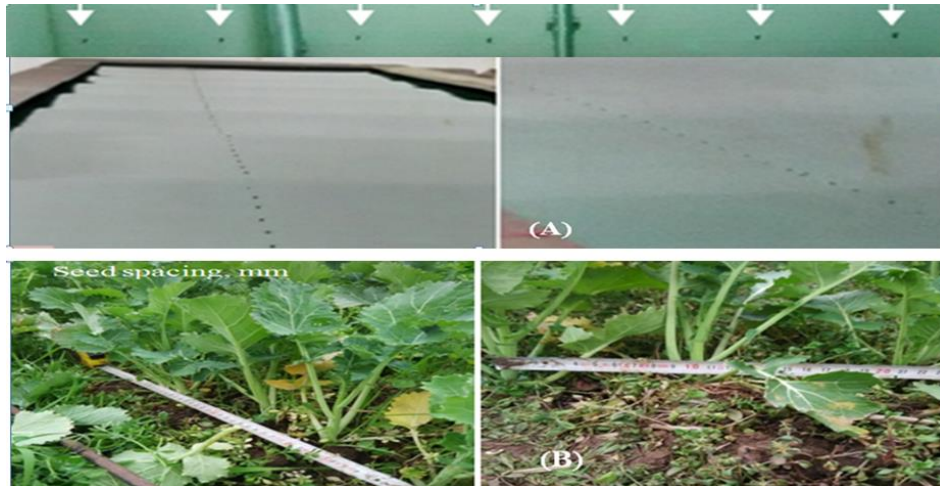


Figure 5: (A) Laboratory seed precision; (B) field seed distribution results.

3.2 Stability of rows quality index, miss index and multiple index

The results of seed precision indices (quality, miss and multiple) coupled with separate stability CV of the rows' quality index was exemplified in [figure 6](#). Figure 6 (A and B) showing up laboratory and field trials outcomes at 15 r/min. Results were evidently viewing that miss and multiple index took place at satisfactory levels. Nevertheless, multiple factor in both methods was rather higher than miss index, which point out that the grain sucking pressure was adequate and suitably applied for attaining acceptable distribution of kernels with a few multiples. As a fact, multiple index increase at low velocity and huge vacuum level while miss is reversely influencing by the two factors. Similar results correspond with those declared by Liao *et al.*, (2017). It could be visibly observed from the two figures that laboratory trials were more stable than field experiments according to the line of stability CV. The highest miss and multiple factors accomplished with laboratory test were 3.88% and 6.26%, while with field trials were 5.38% and 6.23%, respectively. Rows performance under the two methods stated that miss ratio was less than 5.5%, while multiple index was not beyond 6.3%. Stability CV for independent rows replicates in both techniques (which ranged between 1.22 and 2.17%) indicates steady rows results at 15 r/min.

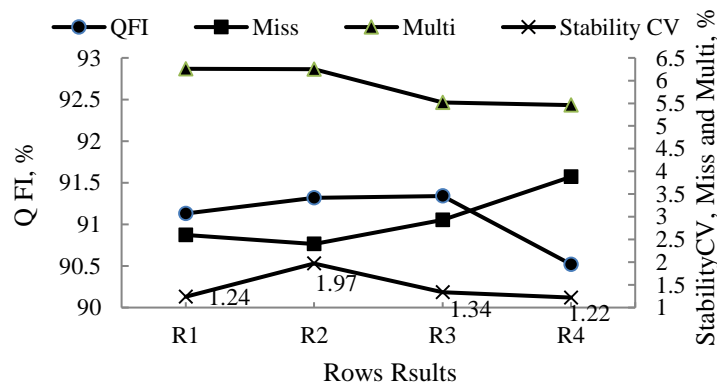


Figure (6 A): Results of laboratory tests at 15 r/min and -1.2 kPa vacuum pressure.

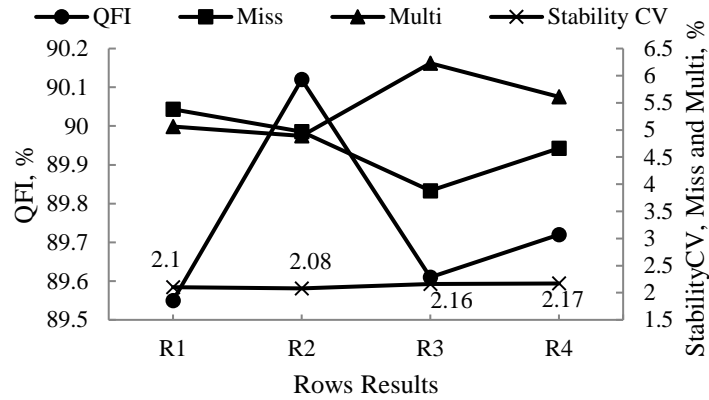


Figure (6 B): Results of field trials at 15 r/min and -1.2 kPa vacuum pressure.

Figure 6(C and D) presenting the impact of the two test techniques on rows kernel preciseness at 20 r/min. Rows' performance of the two methods seemed to be inferior to those achieved at 15 r/min. Quality feed index of the rows' for laboratory tests were not considerably varied as that in field attempts. This could be extremely attributed to better control of laboratory test situations compared to field conditions as previously clarified. Miss and multiple factors were fluctuating among the rows; but multiple factor resulted in higher values as occurred with 15r/min. The highest miss and multiple indexes achieved by laboratory trials were 4.74% and 6.79%, while with field efforts were 5.36% and 8.06%, respectively. Rows' stability CV of laboratory investigations were to some extent closer, but for field experiments they were noticeably differed, particularly of row1 which acquired the poorest results with a stability value of 7.1%. Generally, the stability CV for both methods at 20 r/min was vacillating between 0.88% and 7.1%.

Throughout this work results attained by the two techniques disclosed that laboratory tests can be possibly mastered, but field trials are mostly confronted by a series of obstructions. The lowest mean quality index of the rows under the two methods and at mentioned speeds was above 87%, while miss and multiple factors were not more than 5.4% and 8.1%, respectively. Rows' precision indices were affected by the higher speed larger than the lower one.

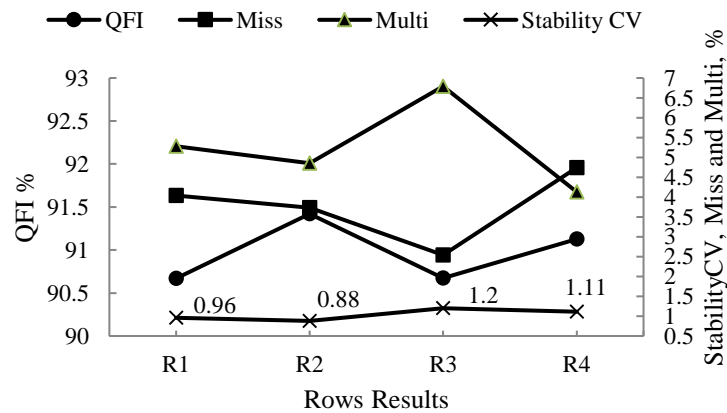


Figure (6 C): Results of laboratory tests at 20 r/min and -1.4 kPa vacuum pressure

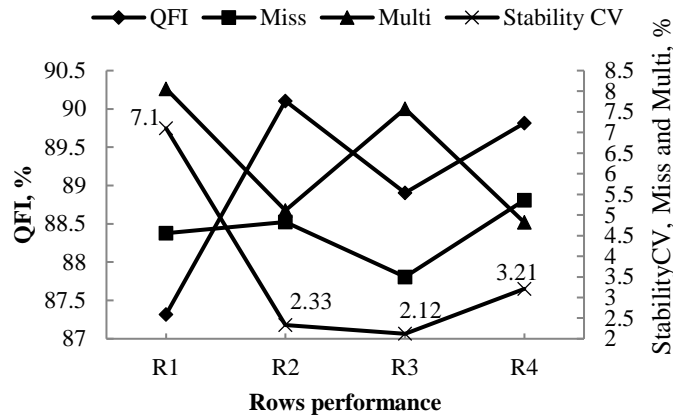


Figure (6 D): Results of field trials at 20 r/min and -1.4 kPa vacuum pressure

4. CONCLUSIONS

The research findings concluded the following points:

1. Laboratory results were found to be better than field operation with quite better results of 15 r/min. than 20 r/min under both methods,
2. field results affected by a set of uncontrollable factors resulted in lower performance,
3. Rows' stability and consistency CV under the two methods were in acceptable ranges,
4. The lowest rows' quality index was found to be around 87.32 %, which attained by field experiment at 20 r/min.

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