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Uniformity of Within-Row Distance in Precision Seeders: Laboratory Experiment

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Abstract: Three vacuum precision seeders' performance was investigated in laboratory studies. Trials were conducted to quantify seed spacing distribution on within-row. In trials, seed spacings uniformity was determined in three within-row distances which were at 14, 17 and 20 cm. The seeders were operated at 1.8, 3.6 and 5.4 km h^{-1} ground speed. Seed spacing distances on the greased belt were measured by hand. MISS, MULT, QFI and PREC index values were used for determining of seed spacing uniformity of seeders. Results showed that there were significantly difference among machines in MULT and QFI index values in $p<0.01$. Operating speed affected MISS index values which changed from 0.96 to 4.51% and seed spacing on within-row affected PREC index values which changed from 13.36 to 17.36%. According to operating speed, the best QFI value obtained at 1.8 km h^{-1} operating speed (96.72%). In QFI values, this operating speed was statistically difference from others in $p<0.10$. At 1.8 km h^{-1} operating speed, the lowest MISS, MULT, PREC values and the highest QFI value were determined as 0.96, 2.32, 14.44 and 96.72%, respectively. After 3.6 km h^{-1}, MISS index value changed statistically. The best within-row distance was 20 cm because of the lowest PREC index values (13.36%).

Key words: Seed spacing uniformity, Miss index, multiple index, quality feed index, precision, within-row distance

INTRODUCTION

Maize (*Zea mays* L.) is cultivated as main crop in early spring and it is drilled as second crop in early summer in sub-tropic countries. Seeds are sown optimum row spacing which depends on seed requirement. The seeder must drill adequate the horizontal placement of seeds in a desired pattern due to limited soil moisture and temperature. Especially, drill procedures are carried out by mechanic or pneumatic planters. Gil and Carnasa (1996) determined that pneumatic drill machines were better result than mechanic drill machines on within-row uniformity. Parish *et al.* (1991) investigated comparison of vacuum and belt seeders for vegetable planting. They informed that vacuum seeders used 90% less seed compared with the then-standard bulk metering planter.

The each seedling that is buried needs to nourishment and sunlight for growth. Suitable row spacing and within-row distance are essential for equal growth of seeds.

Danfors (1987) investigated to equipment for seed placement below a removed and replaced surface tilth. He reported that uniform distribution of the seed in combination with early emergence is expected to improve competition against weeds.

Ball (1986) informed that the competition varies from plant to plant. He notified that the higher yield at higher distances between seeds resulted from the reduction in competition between crop plants and between crop plant and weeds. The yield variation between plants varied between 8 and 14%, respectively.

Bauer *et al.* (2002) carried out a study to determine how surface tillage and subsoiling affect nutrient distribution in the soil profile in narrow-and wide-row systems. They informed that yield of crop changed via row spacing and within-row spacing.

Whitehead and Singh (2000) informed that yield, time of maximum CO_2 exchange rate and leaf-area index of okra are affected by within-row spacing (8, 16, 24, 32, 40 and 48 cm). They obtained that okra plants reached maximum CO_2 exchange rate and leaf-area index earlier and produce higher fruit yield per unit area when spaced close together in the row. Some researcher investigated to effect of plant spacing on water runoff, soil erosion and yield of maize (Mohammed and Gumbs, 1982). They determined that the soil loss from the wide spaced planting which was 31.97 t ha^{-1} was significantly greater than the losses from the close planting, 20.50 t ha^{-1}, in $p = 0.05$. Also, they reported that the closer planting produced significantly more ears than the wide spacing in $p = 0.05$.

To equal emergence of seeds is very important. For achievement of equal emergence, seeds must be sown optimum and equal depth. Gil and Carnasa (1996) were determined that especially on early stage in corn, uniformity of length according to row spacing increased yield up to 5%. Ball (1986) informed that precision drilling can distribute seeds in a similar square grid and yield can be significantly increased compared with conventional drilling. Half of this yield increase can probably be associated with uniform sowing depth and the other half to uniform lateral distribution. While planting, suitable furrow opener (coulter) must be used for uniform horizontal placement. Parish and Bracy (2003) informed that drop height influence seed spacing uniformity. Brown *et al*. (1994) informed that a uniform spaced crop is prerequisite for the achievement of high yields and good quality for rowcrops. For this purpose, they compared experimental dibber drill and coulter drill. They determined that the average total emergence recorded with each of the experimental drills was in excess of 70% compared with 41% for the coulter drill.

After germination, seedling is emergence. Plant spacing can affect growth and yield and plant spacing uniformity begins with seed spacing uniformity (Bracy and Parish, 1998). Nielsen (1991) informed that germination percentage of seed corn typically ranges from 90 to 95% and plant spacing variability depends on misadjusted or malfunctioning planter mechanisms. Jindal and Walker (1987) investigated prediction of within-row plant spacing distributions in cotton at selected population densities. Liu *et al*. (2004) indicated that nonuniform plant spacing within the row has little or no effect on plant growth and grain yield of corn if the plant population is adequate for high yield. They reported that uneven seedling emergence, however, always effects plant growth and reduces grain yield, with earlier emerged plant unable to compensate for lower yield of late-emerging plants. Also, they informed that the yield of an individual plant is influenced not only by the directly adjacent plant but also by a second adjacent plant. Picanco *et al*. (1998) investigated of yield loss in trellised tomato affected by insecticidal sprays and plant spacing. They reported that sprays provided efficient control of *Helicoverpa zea* and *Neoleucinodes elegantolis* in plants at the closer plant spacing.

Bracy and Parish (1998) evaluated that the seeding accuracy of three precision seeders for five vegetable crops using the measures of accuracy as described by Kachman and Smith (1995). They reported that the seeding uniformity of all seeders with elongated (carrot and cucumber) or angular (spinach) seeds were inadequate for precision seeding.

Wilkins *et al*. (1991) developed an equation to provide a Spacing Uniformity Index (SUI). They reported that SUI provided an excellent means for evaluating plant spacing and SUI was used to evaluate the performance of planting equipment.

The main objective of this study was to determine performance of three vacuum precision seeders.

MATERIALS AND METHODS

In this study, the three vacuum pneumatic precision seeders were used for corn drill. Pesticide-treatment corn seed was used in trials. The main dimensions of corn seeds are given in Table 1. As shown in Table 1, spherical coefficient of seed was 0.66. The 1000 seed weight was 286 g. Other the physical specifications of corn which were used in trials were given in Table 2.

The experiment date was end of July and beginning of August 2003. The within-row seed spacing were set at 141, 170 and 205 mm at Machine I; 140, 180 and 205 mm at Machine II and 142, 175 and 208 mm at Machine III. Within-row distances were evaluated 140, 170 and 200 mm for all machines because of similar values. For within-row distance, the transmission rates of machines were arranged between drive wheel and seeding unit. In machine I and II, gears which are between drive wheel and seeding unit were changed for adjustment of within-row distance. In machine III, within-row distances were adjusted via slipping gears which are on the parallel spindle (Fig. 1).

Operating speeds of 1.8, 3.6 and 5.4 km h^{-1} were used for all experiments in laboratory. To avoid bouncing of seeds, greased belt test stand whose width 260 mm and length 4650 mm was used. A seeders row unit was attached on test stand. After experiment, seed spacing in each within-row distance were measured on a stretch 3.0 m for each drill row in three replications (Fig. 2).

Table 1: The main dimensions of seeds

Seed length		Seed thickness		Seed width	
(mm)	(%)	(mm)	(%)	(mm)	(%)
8.51-9.50	2	2.51-3.50	2	6.51-7.50	20
9.51-10.50	22	3.51-4.50	58	7.51-8.50	64
10.51-11.50	54	4.51-5.50	40	8.51-9.50	16
11.51-12.50	22				

Table 2: The physic-mechanic characteristics of seed

			Coefficient of friction (Static)	
Density (kg dm^{-3})	Pile angle (°)	No. of volume grain (No. dm^{-3})	On galvanized metal	On plastic
0.838	21.6	2600	0.4645	0.5976

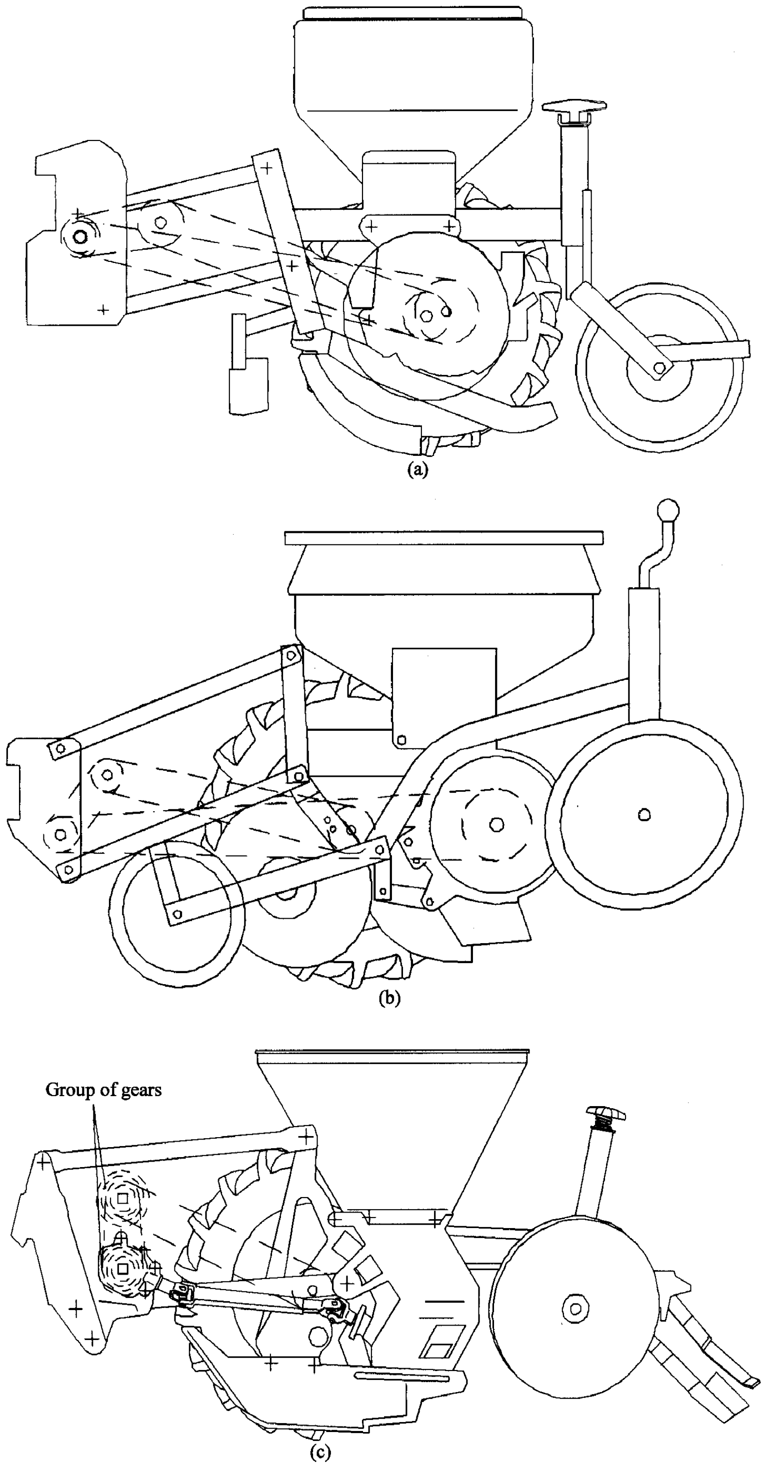
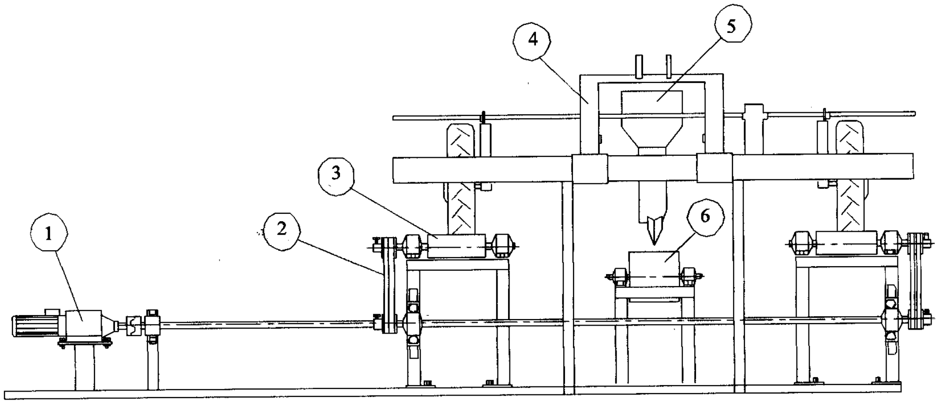
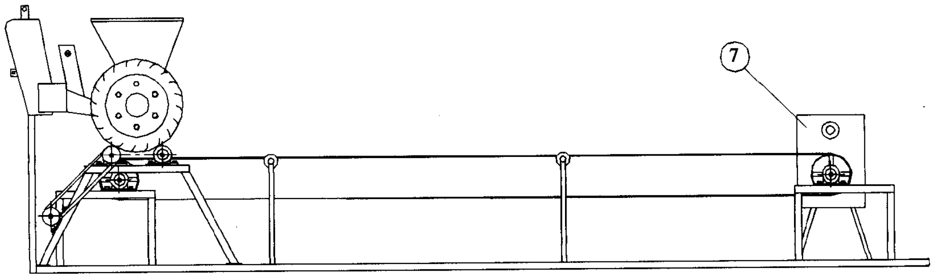


Fig. 1: Transmission of machines (a:Machine I; b:Machine II and c:Machine III)

For evaluating seed spacing uniformity, Miss index (MISS), multiple index (MULT), Quality Feed Index (QFI) and precision (PREC) index values that have been developed by Kachman and Smith (1995). In this method, seeders compare measures of accuracy in seed placement for planters and based on the theoretical seed spacing. Their recommended measures include multiple index (MULT = 0-0.5 of the required spacing), Miss index



(Front)



(Profile)

1. Electronic motor, 2. Transmission unit, 3. Tire drum, 4. frame, 5. Hopper, 6. Greased belt, 7. Mechanism for belt driving

Fig. 2: Test stand in laboratory

(MISS = over 1.5 of the required spacing), quality of feed index (QFI = 0.5-1.5 of the required spacing) and precision (PREC = degree of precision). These methods were also used by Bracy and Parish (1998), Ozmerzi *et al.* (2002) and Ivancan *et al.* (2004).

RESULTS AND DISCUSSION

Seed spacing within-row was measured by hand after experiment. The performance of seeders was evaluated MISS, MULT, QFI and PREC index values.

As shown in Table 3, there were differences among machines in MULT and QFI index values in $p<0.01$. In within-row distance, there was difference only PREC index value in $p<0.01$. Also, in operating speed, there was difference in MISS index values in $p<0.01$. There were differences in QFI and PREC index values in operating speed in $p<0.10$. Moreover, in $p<0.10$, there were difference in MULT and QFI index values in machine and operating speed interactions.

In Table 4, in MISS index values there were no statistically difference between machines and between within-row distances. The lowest MISS index value was in Machine II (1.70%). In within-row distance, the lowest MISS index value was in 20 cm (1.78%). MISS index

Table 3: Variance analysis table of trials

Main factors	df	MISS	MULT	QFI	PREC
Machine (A)	2	0.428 ns	12.464**	6.374**	0.139 ns
Within-row distance (B)	2	0.803 ns	1.245 ns	1.439 ns	8.405**
Operating speed ©	2	3.039**	1.256 ns	2.346 ‡	2.615 ‡
Interactions					
A×B	4	0.111 ns	0.316 ns	0.059 ns	1.526 ns
A×C	4	0.783 ns	2.354 ‡	2.095 ‡	1.659 ns
B×C	4	0.234 ns	1.124 ns	0.683 ns	1.384 ns

F-values, ns: non significant,**: $p<0.01$,‡: $p<0.10$ significant level

Table 4: Seeding uniformity of within-row distance and operating speed

	Measures*			
Factors	MISS (%)	MULT (%)	QFI (%)	PREC (%)
Machines				
I	2.95a	6.79b	90.26b	16.06a
II	1.70a	2.36a	95.94a	15.77a
III	2.77a	0.45a	96.78a	15.51a
Within-row distance (cm)				
14	3.39a	3.68a	92.93a	16.62b
17	2.25a	3.90a	93.85a	17.36b
20	1.78a	2.02a	96.20a	13.36a
Operating speed (km h^{-1})				
1.8	0.96a	2.32a	96.72a	14.44a
3.6	1.95ab	4.34a	93.71a	16.73a
5.4	4.51b	2.94a	92.55a	16.49a

*: Means within a group followed by same letter are not significantly different at p = 0.05 by Duncan's multiple range test

values decreased when distances increased. Because, especially in low distances, to measure of distances between seed need attention. However, there were statistically differences between operating speed in MISS index values. When operating speed was 1.8 km h^{-1}, MISS index value was 0.96%. But, when operating speed was 5.4 km h^{-1}, its value was 4.51%. These values showed that there were no long gaps in 1.8 km h^{-1} but there were in 5.4 km h^{-1}. When operating speed was faster than 3.6 km h^{-1}, the MISS was increased statistically. Nielsen (1994) reported that grain yields at higher speeds were significantly less than lower speeds because of standard deviation of plant-to-plant increasing. He informed that the planted seed rate was significantly different when the planter speed altered. Also, he determined that average yield loss occurred 71 kg ha^{-1} at every 1 km h^{-1} speed increase in the range of 6.4 to 11.2 km h^{-1}. Culpin (1987) informed that when drilling speed was increased from 4.0 to 6.4 km h^{-1}, deterioration increased of spacing distance of sugar beet at target spacing of 15 cm.

In Table 4, in MULT values, there were statistically differences between machines. Machine II and III was better than Machine I in MULT parameter. The best result was in Machine III (0.45%). The worst MULT index value was in Machine I (6.79%). In within-row distance and operating speed, there were no statistically differences in MULT index value.

In Table 4, in QFI values, Machine II and III were statistically difference Machine I. The best QFI value was Machine III (96.78%) and the worst in Machine I (90.26%). However, QFI values of all machines are acceptable limit. Some researchers informed that QFI index values must not below 85% (Kachman and Smith, 1995; Bracy and Parish, 1998). They determined that if QFI index value is below of 85%, the machine is not good for drill. So, in this study, all machines may use for corn drill.

In within-row distance and operating speed, there were no statistically differences in QFI values. In within-row distance, the best QFI value was in 20 cm (96.20%). The worst value was in 14 cm (92.93%). These values were in acceptable limit for drill.

The QFI index values were 96.72, 93.71 and 92.55% in 1.8, 3.6 and 5.4 km h^{-1} operating speed, respectively. According to these values, the more operating speed the less QFI values, however there were no statistically difference between operating speeds.

Efficiency of vibration problem on seed releasing may be reduced via selecting of optimum vacuum degree which alter seed-to-seed. Garcia Lopez and Garcia Barron (1996) investigated that influences of shakes on work precision of pneumatic seeders in laboratory condition. They determined that vacuum had significance level but amplitude and frequencies of shakes had low statistical significance on work precision of pneumatic seeders.

Gil and Carnasa (1996) obtained similar results for comparing seeder performance. They reported that QFI decreased when velocity increased. They informed that decreasing of QFI depended on increasing of MISS values and MULT values remained.

Ivancan *et al.* (2004) investigated effect of precision drill operating speed on the intra-row seed distribution for parsley. They determined that an increase in operating speed results in a decrease of drilling precision because the intra-row seed spacing becomes larger than that required. They reported that an increase of operating speed leads to changes of the values of the drill performance.

In Table 4, PREC index values are not used for determination of uniformity but it is degree for uniformity. Low PREC index values are desirable in trials. In PREC index value, there were no statistically differences among machines. On machines, the lowest PREC index value obtained as 15.51%. PREC values were statistically differences in within-row distances. The best PREC value was determined in 20 cm (13.36%). Within-row distance, 14 and 17 cm, were same group according to Duncan's multiple range test. In operating speed, there were no statistically differences in PREC index values. The PREC index values obtained 14.44, 16.73 and 16.49% in 1.8, 3.6 and 5.4 km h^{-1} operating speed. Kachman and Smith (1995) reported that the highest PREC value must be 29% for uniformity. So these values showed that PREC is within acceptable limit for this experiment.

In machine and operating speed interactions, there were differences in MULT and QFI index values in 0.10 significant level. In this circumstances, the best MULT index value was 0.00% in Machine III and 3.6 km h^{-1} operating speed interactions. The worst MULT index value obtained in Machine I and 3.6 km h^{-1} operating speed interactions (11.15%). The best QFI index value was in Machine II and 3.6 km h^{-1} operating speed (98.14%) and the worst in Machine I and 3.6 km h^{-1} operating speed interactions (85.10%).

CONCLUSION

- There were statistically differences in MULT and QFI values except MISS and PREC index values between machines. Machine II and III were statistically better than Machine I in MULT and QFI values. All machines achieved drill procedure in acceptable limit 85% in QFI values.

- There were statistically differences in PREC index value except MISS, MULT and QFI values in within-row distance. Within-row distance, 20 cm, was statistically better than 14 and 17 cm. All within-row distance were acceptable limit 29% in PREC values.
- There were statistically differences in MISS index value except MULT, QFI and PREC values in operating speeds. Operating speed, 1.8 km h^{-1}, was statistically better than 3.6 and 5.4 km h^{-1}. All operating speed were acceptable limit 85% in QFI values.

Consequently, there were statistically differences between machines, all index values and operating speeds. All parameters were within acceptable limit for precision seeders in laboratory conditions.

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