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The relationship between calibrated and actual field seed rates of the external fluted wheel seed metering device with the use of wide level disk harrow

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ABSTRACT

A field experiment was conducted, at Gedarif University Research Farm, for two consecutive seasons (2006/07 and 2007/08). The objectives of the experiment were to determine the accuracy of external fluted wheel seed metering devices for seeding crops by determining the relationship between the calibrated and actual seed rates for different crops. A wide level disk seeder box equipped with seed metering devices of the external fluted wheel type was used. Five crops of different seed sizes were tested. The calibrated seed rate was determined, using the conventional method when the machine was motionless, and the actual seed rate was determined by using cloth bags to receive seeds when the machine was in motion. The results revealed that actual seed rates were significantly lower than calibrated seed rates for all tested crops. The actual seed rate was 95%, 88%, 96%, 95% and 85% of the calibrated seed rate for sorghum, millet, sesame, sunflower and cotton, respectively. High linear correlations (R^2 = 0.99) between the actual seed rate (dependent variable) and calibrated seed rate (independent variable) were found for all tested seeds. These findings are of considerable importance to farmers and engineers, who use the wide level disk with such type of seed metering devices, to substitute for the reduction in the seed rate in the field.

INTRODUCTION

Seeding operation is one of the factors which affect the productivity of crops. Optimum or recommended plant population is essential for successful crop production. However, to achieve optimum yields, the recommended seed rate varies from one crop to another and for different agro-climatic conditions. Usually, not all the seeds are able to survive through germination and emergence. The factors that affect optimum seed rate include number of seeds per kilogram (seed size), seed viability and crop establishment in the field. The crop establishment is influenced by the quality of the seedbed and its soil moisture content, pests and seeding implement type (Anonymous, 2002). Most of these factors are beyond the control of the seeding machine.

The seed-metering mechanism is the heart of the seeding machine, and it is responsible for distributing seeds uniformly at the desired rate. Several types of metering devices are used in seeding machines, such as vacuum disk, inclined plate, belt, vertical rotor, and fluted wheel (roller). The fluted wheel is the most widely used type in mechanized seeding of crops (Kepner *et al.,* 1978; Srivastava *et al.,* 2006).

The wide level disk (WLD) seeder is the dominant implement used in the mechanized rainfed agriculture of Gedarif area in Sudan. It is an acceptable seeding machine under the wet heavy clay soils of the mechanized rainfed agriculture (Anonymous, 1988). The seed metering devices used in the WLD are usually of the fluted wheels type, which deliver more or less continuous flow of seeds (Kepner *et al.,* 1978). This type of seed metering device has the ability to seed a wide range of seed sizes (Emam and Younis, 1992; Ali, 1996). The rate of seeding with the fluted wheel is controlled by either changing the length of the flute exposed to the seeds in the seed box or by changing the drive gear ratio or both (Hunt, 1976; Kepner *et al*., 1978; Culpin, 1986).

One of the main functions of a seeding machine is to meter the required amount of seeds (Kepner *et al.,* 1978; Srivastava *et al.,* 2006). However, Hunt (1976) mentioned that not many metering mechanisms have an exact ratio between the setting and the actual amount of delivered seed. Also, Saeed and

Eissa (2007) reported that the sowing of sorghum by the WLD at 6.4 kg/ha seed rate resulted in lower plant population than the sowing by the row crop planter (culti-planter) at 6.0 kg/ha.

For the seed rate calibration of the WLD seeder, the land wheel (drive wheel), number of seed metering devices and actual width of sowing are usually considered. The traditional calibration of this machine is achieved by raising up and rotating the land wheel. The assumption in this study is that the free rotation of the drive wheel at calibration is not the same as when the machine is working in the field because the soil surface conditions affect the drive wheel rotation and jumping that affects the final seed rate. In fact, the crop stand in farmers' field is less than the optimum plant density when using the WLD, which resulted in lower crops yield. Therefore, for crop yield improvement, the performance of seeding machines should be improved.

This study was intended to identify and quantify the accuracy of the fluted wheel seed metering system with the use of WLD for seeding seeds of different sizes and to determine the relationship between the calibrated and actual seed rates for five selected crops.

MATERIALS AND METHODS

Experimental location

The experiment was carried out for two consecutive seasons (2006/07 and 2007/08) at Gedarif University Research Farm in a heavy clay soil (65%). The experimental site was tilled by a WLD plow to 5 - 8 cm depth in preparation for the intended field test. At the time of executing the experiment, the average soil moisture contents were 17.5% and 24.3% for the two seasons, respectively.

Machine used

Trailed WLD plow, with a seeder box having 24 disks arranged in four gangs with a disk diameter of 49 cm, was used. It possessed five seed metering devices of the external fluted wheel type. Specifications of the seed metering device used are depicted in Table 1. A rear-wheel drive Massy Ferguson tractor was used to pull the machine.

Machine working pattern

The machine was hitched to the tractor at a tilted angle to give an actual working width of 3.7 m. Its working pattern was from boundaries towards the middle of the field in a counter clock-wise direction. Because the machine was tilted, the land wheel did not rotate smoothly. The main drive shaft of the seed metering devices takes its motion from the land wheel by means of chains and sprockets of different diameters and teeth numbers, and no seed tube was used. The machine parts involved in the seed calibration were the seed metering devices, a hand lever, which permits lateral movement of the metering devices, land wheel (drive wheel) and the actual width of seeding.

Table 1. The specifications of the external fluted wheel seed metering device

Specification items	*Measures*
Material	Cast iron
Type of flute	Axial
Total number of flutes	12
Total length of flute	3.7 cm
Effective length of flute exposed to seeds	3.0 cm
Outer flute diameter	5.1 cm
Inner diameter of flute	4.0 cm
Depth of flute	1.1 cm
Width of flute	1.1 cm
Effective volume of a single flute	1.4 cm^3
Seed inlet area	14.7 cm^2
Flute drive shaft cross-sectional dimensions	1.6 X1.6 cm

Tested crops

Clean seeds of the common crops grown in the mechanized rainfed areas of Gedarif were used, which were sorghum, sesame, pearl millet, cotton and sunflower. The cotton seeds were chemically delinted. The seed characteristics and the optimum seed rates of the tested crops are presented in Table 2.

Table 2. Some characteristics and optimum seeding rate of five crops

Crop	1000-seed weight (g)	Bulk density (g/l)	No. of seeds per kg	Optimum seed rate (kg/ha)	Optimum plant population (000/ha)
Sorghum	30.14	724.1	33179	7.1	100 – 133
Pearl millet	19.33	827.3	51733	-	-
Sunflower	46.95	421.0	21299	2.4 – 4.1	22 – 36.9
Sesame	3.5	635.5	285714	3.6	214 – 238
Cotton	107.18	409.3	9330	11.9 – 14.3	59.5 – 78.6

Measurements

Implement drive wheel circumference, actual seeding width and distance traveled by the machine were measured using a measuring tape. The collected seeds from calibrated and actual field tests were weighed using an electronic-sensitive balance.

Calibration of the machine

For the seeding machine calibration, the drive wheel was initially raised and rotated many times to ensure that the seed metering system took its full capacity and delivered out the seeds. A mark was made on the drive wheel to determine its number of revolutions. Then, a labeled cloth bag was tied to each seed metering device to receive seeds. The drive wheel was rotated manually for 15 revolutions. The calibrated seed rate was determined according to the following formula:

$$CSR = \frac{TW \times 10000}{DWC \times N \times W}$$

where:

CSR = calibrated seed rate (kg/ha)

TW = total seed weight (kg)

DWC = drive wheel circumference (m)

N = number of revolutions of the drive wheel

W = actual seeding width (m)

10000 = conversion factor (constant) from m^2 to hectare

To determine the actual field seed rate, a labeled cloth bag was again tied to each seed metering device and the implement was moved to a distance of 30 meters. The total collected seeds were then weighed. The actual field seed rate was determined according to the following formula:

$$ASR = \frac{SWT \times 10000}{D \times W}$$

where:

ASR = actual field seed rate (kg/ha)
SWT = seed weight (kg)
D = distance traveled (m)
10000 = conversion factor (constant) from m^2 to hectare

The calibrated and actual field seed rates were taken one after another and repeated three times for each adjusted seed rate. For each crop, five random seed rates were tested.

Statistical analysis

Paired sample t-test was carried out to explore and evaluate the differences between the calibrated and actual field seed rates according to the procedure described by Snedecor and Cochran (1989). Moreover, the accuracy percentage (AC %) of the actual field seed rate compared to the calibrated one was determined according to the following formula:

$$AC (\%) = \frac{(ASR) \times 100}{CSR}$$

where:

AC (%) = accuracy percentage

ASR = actual field seeding rate

CSR = calibrated seeding rate

Then the reduction percentage (Red (%)) in the actual seed rate was determined as follows:

$$Red (\%) = 1 - AC (\%)$$

Regression between calibrated and actual field seeding rates was established. In addition, some descriptive statistical measurements were used, such as mean, standard deviation, maximum and minimum values as well as coefficient of variation.

RESULTS AND DISCUSSION

There was a reduction in the actual field seed rate from the calibrated seed rate for all tested crops (Table 3). Results showed that the actual field seed rates were significantly lower than the calibrated seed rate for all tested crops (Table 4). This was probably due to the inefficiency of the fluted wheel type seed metering device to give the same calibrated seed rate in the field. Additionally, the high lateral thrust on the tilted land wheel reduced the number of wheel revolutions. Moreover, Srivastava *et al.* (2006) reported that slippage of the drive wheel reduces the seed rate.

Table 3. Accuracy of fluted wheel seed metering device for seeding different crops for two seasons (2006/07 and 2007/08).

Sample No	CSR	ASR	AC (%)	CSR	ASR	AC (%)
	2006/2007			2007/2008		
			Sorghum			
1	49.18	48.12	97.84	51.27	50.30	97.29
2	36.40	36.03	98.98	35.94	34.42	95.77
3	27.91	27.68	99.18	29.56	29.13	98.56
4	13.39	12.46	93.06	20.22	18.13	90.66
5	4.31	3.60	83.60	11.57	11.09	95.86
			Pearl millet			
1	64.57	58.77	91.02	59.26	50.76	85.66
2	51.91	49.05	94.50	38.98	34.09	87.45
3	31.83	27.94	87.78	26.62	24.61	92.43
4	12.03	11.13	92.54	20.05	16.57	82.65
5	1.89	1.73	91.31	14.93	11.44	76.62
			Sesame			
1	25.29	24.08	95.24	46.22	45.94	99.39
2	18.14	17.43	96.08	31.01	30.77	99.21
3	12.59	12.14	96.43	16.22	15.80	97.37
4	6.36	4.97	78.11	7.82	7.98	102.08
5	2.16	1.93	89.20	2.08	2.29	109.96
			Sunflower			
1	31.01	30.41	98.06	38.61	37.44	96.97
2	24.81	24.10	97.15	27.05	26.55	98.13
3	14.46	13.11	90.63	19.58	18.36	93.80
4	4.73	4.23	89.36	13.36	12.74	95.41
5	2.73	2.67	97.77	6.67	6.43	95.17

			Cotton			
1	37.70	33.72	89.43	43.27	38.32	88.56
2	34.41	33.72	98.01	28.12	27.09	96.36
3	18.46	16.47	89.25	16.31	16.24	99.61
4	9.37	7.09	75.64	9.15	8.20	89.62
5	2.85	1.60	55.95	5.51	3.53	64.09

CSR = calibrated seed rate (kg/ha), ASR = actual seed rate (kg/ha), AC (%) = accuracy percent

Table 4. Paired sample t-test for calibrated and actual field seed rates for five crops.

	Sorghum	Pearl millet	Sunflower	Sesame	Cotton
Variance of difference between means	0.0312	1.1385	0.0173	0.0273	0.2298
Standard deviation	0.1765	1.0670	0.1315	0.1653	0.4793
T value	5.1101	2.5285	5.3686	2.7590	3.9992
Df	9	9	9	9	9
Probability of t	0.0006	0.0323	0.0005	0.0221	0.0031
Confidence limits	0.503 to 1.301	0.284 to 5.112	0.409 to 1.003	0.082 to 0.830	0.833 to 3.001

The seeding machine caused losses in crop seeding rate by 5%, 12%, 4%, 5% and 15% for sorghum, pearl millet, sesame, sunflower and cotton, respectively (Table 5). The reduction in the actual field seed rate might be due to losses in transmitting the mechanical energy from the drive wheel to the final drive shaft as the result of drive wheel slippage or slag in connecting chains. The results also showed that there was no specific trend in accuracy percentage according to the seed rate or seed size. This means that the reduction happens irrespective of the adjusted seeding rate or seed size.

Statistical analysis for accuracy percentage of the seed rate for all tested crops is depicted in Table 5. The average accuracy in actual field seed rate, compared to the calibrated seed rate was 95%, 88%, 96%, 95% and 85% for sorghum, pearl millet, sesame, sunflower and cotton, respectively. The highest average accuracy was obtained for sesame, sorghum and sunflower seeds. The lowest average accuracy was obtained with cotton seeds, which might be due to the fact that cotton seeds are less homogenous. The coefficient of variation in the accuracy of seed rate also varied, and the highest and the lowest coefficients were obtained with cotton seeds (11.39%) and sunflower seeds (3.27%), respectively. These results indicated that the fluted wheel seed metering device is less accurate in seeding cotton seeds than the other crop seeds.

The results of the regression analysis showed a high correlation (R^2 = 0.99) between the actual field seed rate and calibrated seed rate. The relationship was linear for all tested seeds (Table 6). This means that the increase in calibrated seed rate was followed by an increase in actual field seed rate. Also, a general linear equation was drawn to predict the actual field seed rate from the calibrated seed rate.

The results indicated that using the traditional calibration method reduced the actual field seed rate and hence reduced the final yield. Therefore, the reduction in the calibrated seed rate that occurred when using a machine having a fluted wheel seed metering device should be taken into consideration in the field.

Table 5. Statistical analysis for accuracy percent in actual field seed rate for different crops for two seasons (2006/07 and 2007/08).

	Sorghum	Pearl millet	Sesame	Sunflower	Cotton
Average	95(5)	88 (12)	96 (4)	95 (5)	85 (15)
Std.	4.9	5.4	8.6	3.1	14.7
C.V.%	5.12	6.16	8.63	3.27	17.39
Max	99.2	94.5	110	98.1	99.6
Min	83.6	76.6	78.1	89.4	55.9

Values between brackets refer to the average reduction percent (Red %).

Table 6. Regression analysis for calibrated and actual field seeding rates for five crops.

Tested crop	Simple regression equation	R^2
Sorghum	ASR = 0.9918CSR - 0.6714	0.998
Pearl millet	ASR = 0.9082CSR - 0.6426	0.994
Sunflower	ASR = 0.982 CSR - 0.0692	0.999
Sesame	ASR = 0.9958CSR - 0.3876	0.998
Cotton	ASR = 0.9435CSR- 0.7574	0.991
General equation	ASR = 0.9401CSR – 0.1287	0.991

ASR = actual seed rate (kg/ha), CSR = calibrated seed rate (kg/ha).

CONCLUSIONS

1- The tested seeds and the measured variables represented good indicators for the determination of the accuracy of the fluted wheel seed metering devices.

2- The actual field seed rate was found to be significantly lower than the calibrated seed rate for all tested crops seeds.

3- The average accuracy of actual field seed rate was 95%, 88%, 96%, 95% and 85% compared to the calibrated seed rate, for sorghum, millet, sesame, sunflower and cotton crops, respectively.

4- There was no definite trend in accuracy due to the seed rate or seed size.

5- High correlation coefficients were obtained between the actual field seed rates (dependent variable) and the calibrated seed rate (independent variable), and the relationship was linear for all tested seeds, with R values of 0.99.

6- The results are of considerable importance to farmers and engineers to substitute for the reduction in the field seed rate with the use of such type of seed metering devices, in the wide level disk

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العلاقة بين معدلات البذار المعايرة والفعلية في الحقل لجهاز تلقيم البذور ذو العجلة الخارجية المموجة المستعملة في الدسك العريض

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الخلاصة

نفذت تجربة حقلية بالمزرعة التجريبية لجامعة القضارف على مدى موسمين متتاليين (07/2006 و08/2007). هدفت التجربة لتحديد مدى دقة جهاز تلقيم البذور ذو العجلة المموجة الخارجية لزراعة المحاصيل من خلال إيجاد العلاقة بين معدلي البذار المعاير والفعلي لمحاصيل مختلفة. أستخدم المحراث القرصي العريض المزود بصندوق بذور و به أجهزة تلقيم بذور من النوع ذو العجلة المموجة الخارجية. اختبرت خمسة محاصيل ذات بذور بأحجام مختلفة. تم تحديد معدل البذار المعاير باستخدام الطريقة التقليدية عندما تكون الآلة في وضع توقف وتم تحديد معدل البذار الفعلي باستخدام أكياس من القماش لاستقبال البذور عند ما كانت الآلة في وضع الحركة. أوضحت النتائج أن معدل البذار الفعلي أقل معنويا من معدل البذار المعاير لكل المحاصيل المختبرة. و بلغ معدل البذار الفعلي 95% و 88% و 96% و 95.2% و 85% من معدل البذار المعاير لمحاصيل الذرة الرفيعة، الدخن، السمسم، زهرة الشمس والقطن على التوالي. كان هنالك معدلات ارتباط خطية عالية ($R^2 = 0.99$) بين معدل البذار الفعلي (المتغير التابع) ومعدل البذار المعاير (المتغير المستقل) لكل البذور المختبرة. هذه النتائج ذات أهمية كبيرة للمزارعين والمهندسين، الذين يستخدمون هذا النوع من أجهزة تلقيم البذور مع المحراث القرصي العريض، عند تحديد معدلات البذار المطلوبة بطريقة صحيحة.