Available online at www.uofk.edu
Proceedings Vol. 1 pp. 225 -234
Annual Conference of Postgraduate Studies and Scientific Research
17-20 February 2012-10-17 Friendship
Hall, Khartoum

On-The-Go Assessment of Seed Metering Unit Performance Using an Opto-Electronic Sensor

O. Hajahmed[1], E. Tola[2], A. F. Kheiralla[3], K. Algaadi[2]

[1]*Tital Company Ltd, Obeid Khatim Street, 11192 Khartoum Sudan*
(Tel: 249-911111197; e-mail: osama.hajahmed@ gmail.com.)
[2]*Collage of Food and Agricultural Sciences, King Saud University*
Rayadh 11451, Saudi Arabia (e-mail: klhtola63@yahoo.com)
[3] *Department of Agricultural Engineering, Faculty of Engineering, University of Khartoum,*
Khartoum 321, Sudan. (E-mail: kheiralla65@yahoo.com)

Abstract: The main objective of a seeding machine is to put seeds at a desired depth and spacing within the row. Seed spacing uniformity is one of the most important criteria in evaluating planter performance. Therefore, the objective of this research work was to develop an opt-electronic monitoring system for assessment of a mechanical planter seed metering unit performance. The developed system was used to monitor seed flow and to measure seed spacing from the metering system of the row crop planter. The developed system comprised of an optoelectronic sensor for seeds detection, a rotary encoder for forward speed and seed position measurement, amplifiers for adjusting sensors signals, a microcontroller for synchronizing sensors signals, and a PC for operating the program and displaying process. The developed system has been successfully tested on chickpeas seeds at two operating speeds (1.3 m/s and 1.9 m/s). Both numbers and locations of the dropped seeds were assessed. The results indicated that the developed system can be accurately used to detect seeds flow from the metering system with overall system errors of ±4% and ± 10% for speeds of 1.3m/s and 1.9m/s, respectively, compared to manual measurements. Further extensive testing on different crops under actual field conditions are highly recommended to ensure reliability of the developed system.

Keywords: *Opto-Electronic Sensor; Precision Farming; Seed Metering; Seed Spacing.*

1. INTRODUCTION

Planting machines generally are provided with plurality of dispensing units carried on a single frame for simultaneously dispensing the material over a plurality of uniform rows. Electronic monitors coupled to the dispensing units by way of appropriate sensors, are well known for providing the farmer with reasonable means to monitor the dispensing process and ensure against over and under distribution. Monitors provide a way to observe seed population planted by each planting or dispensing unit, as well as by the planting machine as whole. In order to determine seed population planted by each planting unit, as well as by the planting machine as a whole, it is necessary to determine the number of seeds planted by each planting unit of the planting machine, the ground speed of the planting machine , the numbers of rows being planted, and the row width or spacing between rows. And as well know the quality of confection crop seed harvested, specifically seed size and uniformity of size, is dependent on plant population and uniformity of plant spacing within the row.

One of the most important criteria in evaluating planter performance is seed spacing uniformity. The distance between plants within a row is influenced by a number of factors including variability in planter metering and seed dropping, failure of a seed to be dropped, multiple seeds dropped at the same time, seed trajectory, and seed bounce in the furrow, as well as seed emergence factors [1].

The main objective of seeding is to put seeds at a desired depth and spacing within the row. Uniform seed spacing and depth result in better germination and emergence and increase yield by minimizing competition between plants for available light, water, and nutrients [2 & 3]. The quality of horizontal and vertical distribution of seeds is influenced by row spacing, sowing depth, soil conditions, seeder design, seed density, and operator skill [2], Plant population is an important factor in crop production, which can affect growth and yield and this to a great extent depends on the performance of the metering mechanism. Robinson et al. [4] studied the effect of uniformity of plant spacing within the row on sunflower yield and quality. They found that uniformity of plant spacing within the row affected yield, seed size, and consistency of seed size in some of the sites and years of their study. Thus, both seed population and seed spacing at planting time have effects on the harvested seed yield and seed size. Examples of studies conducted to determine the effect of plant population on seed quality include projects by [5 & 6]. Both studies found that specific plant populations provided maximum yield depending on test location. Both studies also showed that seed size generally decreased as plant population increased.

Several researchers have published results from comparisons of planter models, field speeds for seed spacing accuracy as delivered by the planter. Mollanen et al. [7] compared four planter models on a grease belt test stand, each with several options, at three field speeds with three seed sizes, for a 'planter index'. They found that seed spacing accuracy differences is among planter models, among options within models, among field speeds, and among seed sizes. Allen et al. [8] also found differences in seed spacing accuracy caused by planter model, seed size, and field speed. Panning et al. [9] used the opto-electronic sensor system for laboratory evaluation of the seed spacing uniformity of a John Deere 71 Flexi-planter, a John Deere MaxEmerge II planter, and a Kleine Unicorn-3 planter. Each planter was operated at simulated planter travel speeds of 3.2, 5.6 and 8.0 km/h while planting regular-pelleted sugar beet seeds with a target spacing of 15 cm. They commented that tests in the lab using the optoelectronic sensor system allowed the planter performance to be determined quickly, and with less variation than that obtained from field testing. Y. Lan et al. [10] concluded that within the error range caused by the elevation difference between the opto-electronic photogate sensor and the grease belt, the seed spacing data obtained from the two systems were not significantly different. The opto-electronic system can be used instead of a grease belt test stand to obtain rapid quantitative laboratory evaluations of planter seed spacing uniformity. The optoelectronic sensor system, with 3 mm diameter LEDs and phototransistors, worked well to obtain 508 seed spacing's for regular-pelleted and mini-pelleted sugarbeet seeds and pelleted chicory seeds. The opto-electronic system missed two seeds and detected two phantom seeds out of 170 seed spacing's with medium- encrusted sugarbeet seed.

The importance of seed monitoring system is meant to observe seed population planted by each planting or dispensing unit, as well as by the planting machine as whole. In the typical planting operation, a number of planters, (each has a hopper for containing seeds and a chute which extends near the ground) are pulled by a tractor. If one or more of the planters becomes inoperative, it is apparent that unless the tractor operator is aware of the malfunction, a crop deficiency will result. It is not possible for the tractor operator to control the tractor and at the same time watch all of the planter units. It is therefore very desirable that the tractor operator be able to monitor the output of the planters and simultaneously control the tractor. Many types of seed monitoring system had been designed, developed and patented. According to Schenkenberg [11], indicating system had been proposed whereby the tractor driver could watch flashing lamps which were supposed to indicate whether the planters are operating properly. These indicating systems generally utilized a sensing device comprising a mechanical switch, which is actuated as a result of physical contact thereto by a seed passing through the chute. Such an indicating system is disclosed in the US patent to J. D. Young, No. 2,907,015, issued Sept. 29, 1959. However, the mechanical switches that are used must be highly sensitive, and serious problems with such switches have occurred by reason of dust and moisture getting into the switches and causing a malfunction. The US patent to Fathauer et al. [12], a Wireless seed detecting and monitoring apparatus includes one or more transmitter units mounted at the seed planter and a receiver unit mounted in a monitor console located at remote location. Seeds being planted produce a signal which modulates an r-f transmitted signal during the planting operation .A receiver is responsive to the r-f transmitted signal and detects the modulated signal information corresponding to seeds being planted. This detected signal is then delivered to monitoring circuitry to indicate the operation of the seed planter. The US patent to O'Neall and Borovec [12], a standalone monitoring apparatus is provided for monitoring a plurality of selectable functions of an agricultural planter. This includes a plurality of seed sensors, each associated with a corresponding seed dispensing unit and generating a seed signal representative of the depositing of a seed by the memory .the monitoring apparatus is intended to monitor signals from up to 16 seed sensors.

The overall objective of this study was to design, develop and test an opt-electronic monitoring system for assessment of mechanical planter seed metering unit performance in the laboratory. The works involve:

- To design and develop monitoring system which is comprised of an opt-electronic sensor, encoder, microcontroller, amplifier, and computer
- To evaluate the performance of the developed system based on monitoring seed flow and measurement of seed spacing.

2. MATERIALS AND METHODS

2.1 Test Platform

A Mechanical crop planter (4 rows, ATESPAR, Turkey brand assembled by GIAD Company in Sudan) with fertilizer application facility was selected as the test platform (Fig. 1.a). It is adjustable setting for both of interrow and overrow. Assembling the machine to the tractor is done through the use of the three hitch point (linkage) system. Able to sow seeds like: chickpea, bean, kidney, maize, nuts, sunflower, pumpkin cereal, melon, watermelon, soybean, pea etc.

The planter metering mechanism includes horizontal seed plates for metering seeds. Cells along the periphery of the plates were sized to match the seed dimensions, so that only one seed could fit in each cell. As each cell passing the seed tube, a spring-loaded knockout device would push the seed into the seed-tube. Plates were easily replaceable (Fig. 1.b). The transmission system (consists of a series of chains, and gears) used to apply variable speeds to the seed plate to give the desired seed spacing.

2.2 Test Seeds

Chickpea seeds (Cicer arietinum, L. Fam. Fabaceae) were used for this study. Seeds used for the experiments were sorted and graded using sieves. The seed diameter is between (3.18mm and 9.52 mm) and the average seed weight was 23g/100seeds.
The opto-electronic monitoring system consisted of optoelectronic sensor for seed detection, Encoder for forward speed and seed position measurement, amplifiers for adjusting sensors signals to the microcontroller, microcontroller to synchronize sensors signals, and a PC to operate the program and monitoring the system (Fig. 2).
The experiments were carried out using mechanical crop planter (4 rows, ATESPAR, Turkey) coupled to an alternative current motor (220 Volt, 0.4 kW) via gearbox having two speeds of 1.3 m/s and 1.9 m/s (Fig. 3). The integrated system collected multi-sensor data and store the information in database. The different components and how they were integrated are described in the following sections.

2.5 System Components

Opto-electronic Sensor**:** The Opto-electronic sensor (OMRON Corporation, Japan) used in the system was a Digital Fiber Sensor E3X-DA-S This unit is used to capture the seeds as they exit from the drop tube. The sensor is applying sensing distance of 1300 mm and the sensing width is 30 mm. Fig. 4 illustrates the Opto-electronic sensor fiber head while Fig. 5 illustrates the Fiber Head connected to the seed tube.

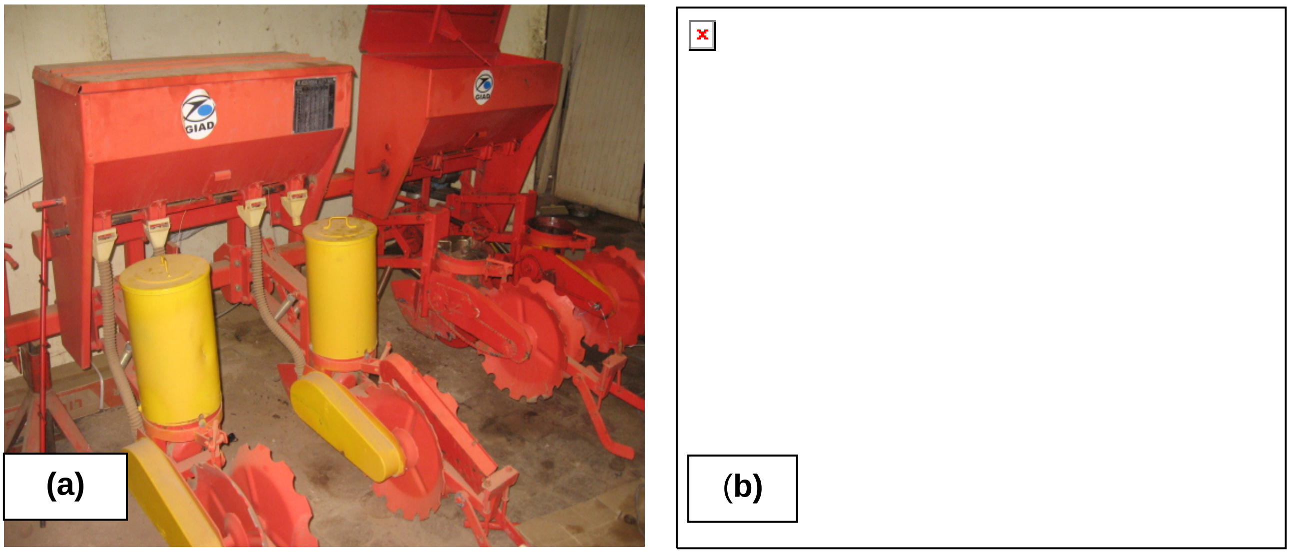

Figure. (1). (a) Tested Seeder (Model ATESPAR, GIAD, Company), and (b) Seed metering mechanism

Rotary Encoder: The rotary encoder (Model E6B2-CWZ6C, OMRON Company, Japan) used in the system to detect position and speed of the travel wheel which utilized to calculate the in row spacing between the planted seeds. The selected rotary encoder has a wide operating voltage range of 5 to 24 VDC and resolution of 200 PPR (pulses/rotation).
The shaft of the rotary encoder was connected with a chain gear in the travel wheel, via the extended shaft in the gear and coupling (Model E69-C06B, OMRON Company, Japan) as shown in Fig. 6.
Microcontroller*:* To integrate the functions of the system components an Atmel ATMega16L microcontroller was used. It has a digital supply voltage, and four ports (A, B, C, and D). A port serves as the analog inputs to the A/D Converter and also serves as an 8-bit bi-directional I/O port. The C-language software program was used as an easy way to implement communication with both sensors

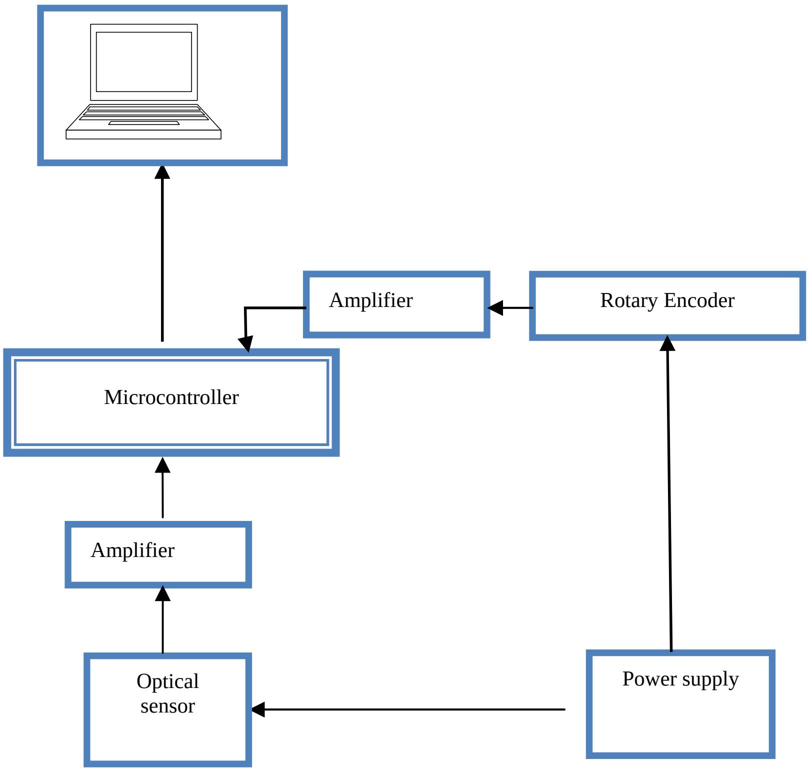

Figure (2). Block diagram opto-electronic monitoring system

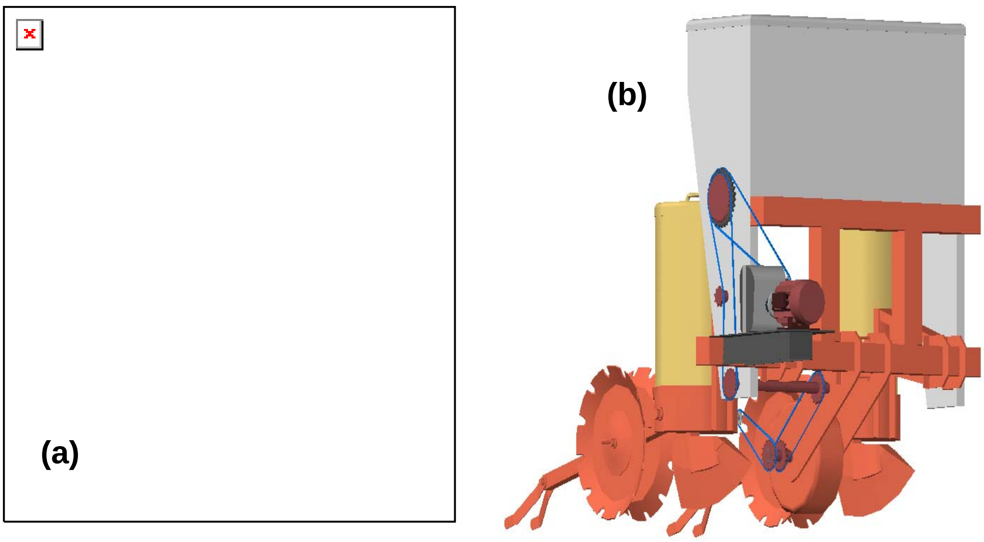

Figure (3). (a) Experimental setup, (b) AC motor coupled to transmission system

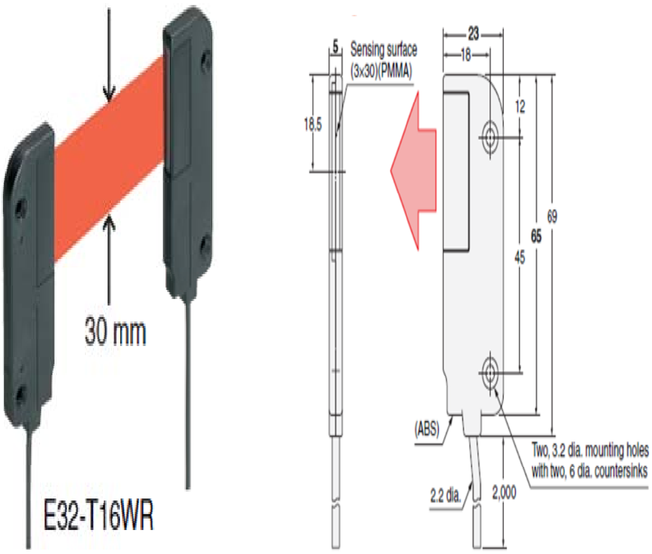

Figure (4). The Opto-electronic sensor Fiber Head

Figure (5). The Fiber Head connected to the seed tube

Figure (6). Rotary Encoder Connection

2.6 Monitoring System Development

A C++ software program, to integrate the functions of the system components, has been successfully developed. Tests were conducted under stationary conditions, using chickpea seeds, and with variations in ground speed using an electrical motor (220 V, 0.4 kW), jointed with variable speed gear box giving two speeds of 1.3m/s and 1,9 m/s. Fig. 7 below represents the system flowchart. The developed program was executed in the Code Vision AVR to operate the Microcontroller and the Program window output was presented in Visual studio as shown in Fig. 8. The integrated system collected multi-sensor data and store the information in database.

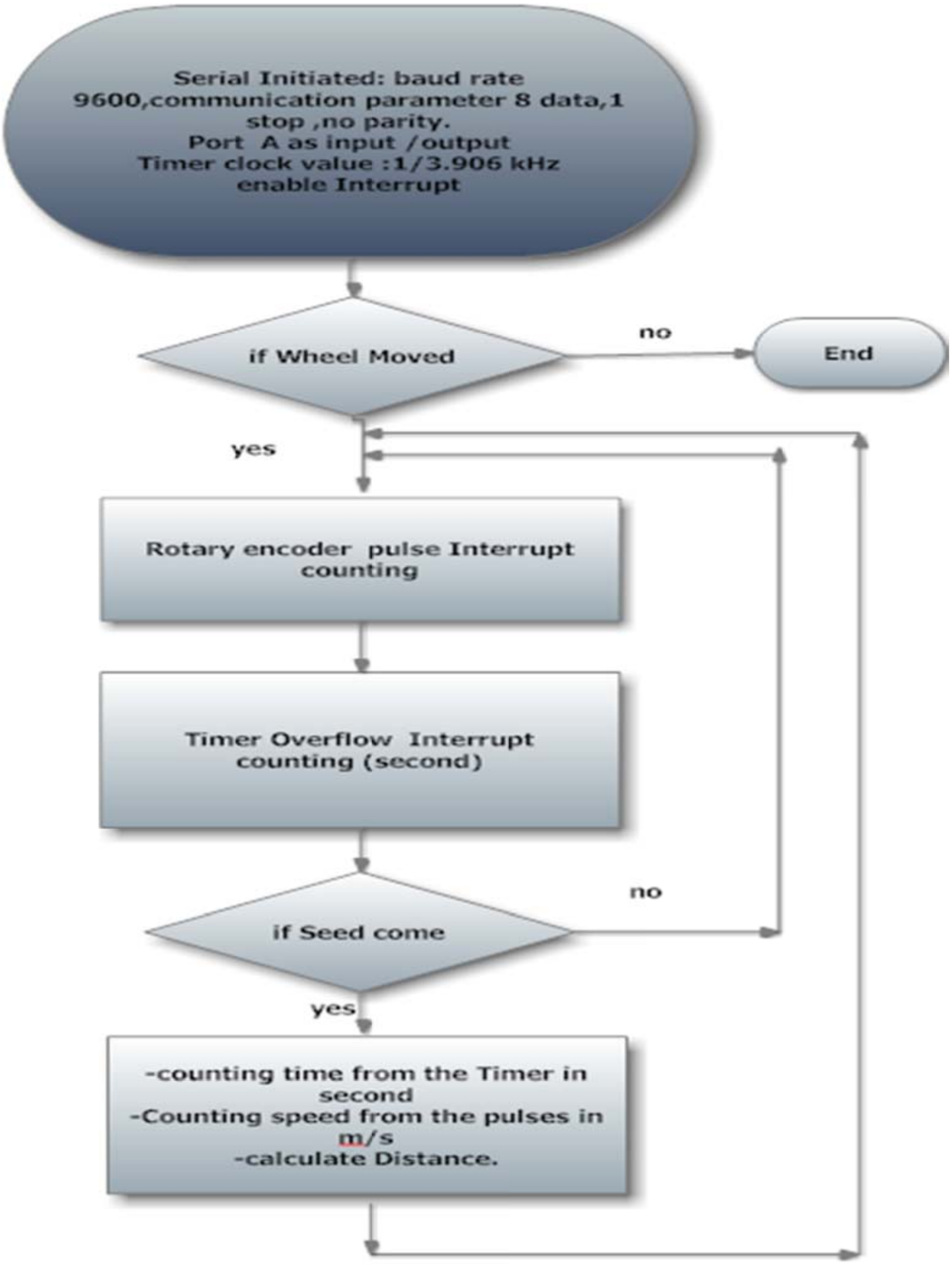

Figure (7). The system flowchart

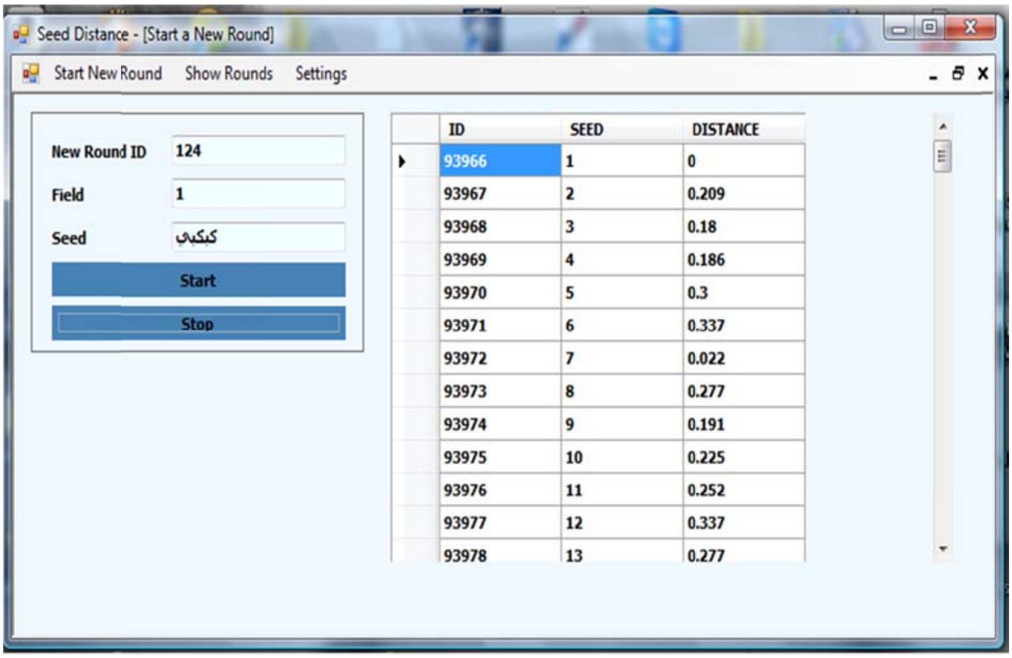

Fig (8). The Program Window

2.7 System Setup and Calibration

The system components were setup, calibrated, and the system performance of each component was evaluated separately. Experiments were carried out under various speeds and target seed spacing. Experiments to evaluate the performance of the developed system were conducted under two operating speeds of 1.3m/s and 1.9 m/s for one seed metering unit, using a seed plate of 10 cells. Chickpea seeds were used for these experiments. Observations were taken for three replicates at each gear position and operating speed. The monitoring system reading is based on the time intervals because the reading of the sensor for each 20 sec. were compared with the actual number of seeds collected, and seeds spacing in the row was recorded.
The head of the optoelectronic sensor consisted of a sender and a receiver. The sender is placed in one side of the seed flow path and the receiver is placed on the other side of seed flow path optically aligned with the sender and it was adjusted to the best alignment and resolution. The head emits an electrical signal when a seed passes between the sender and receiver. Amplifier was used to magnify the signal which recorded through the Microcontroller in the data base at the same time the signal will generate interrupt to the Rotary Encoder in the program to define this point and record it in the data base and start counting from this point to calculate the spacing between the consequent seeds. Using the opto-electronic sensor will help the operator (driver) to follow the record on the monitor for immediate action against improper work indication. And the data base allows for further analysis of data which can be used in after planting field operations assessment.

2.9 Computation in Rotary Encoder Circuit

Knowing the diameter of the seed metering drive wheel (40cm), resolution of the rotary encoder fitted in the center of the wheel base to count the number of rotations, seed position and seed spacing could be calculated using equation (1) as follows:

$$D = N * d * \pi * t \qquad (1)$$

where D is the distance between seeds, in m, N the driving wheel speed, in rpm, d the driving wheel diameter, in m, and t the time intervals between seeds, in minutes.

3. RESULTS AND DISCUSSION

Figures 9 and 10 show comparison of the test results derived from the system and from a manual measurement with the forward speed 1.3m/s and 1.9m/s, respectively. Each speed has different gear combination setup and each group of seed was replicated 3 times to help in validating the consistency of the results.

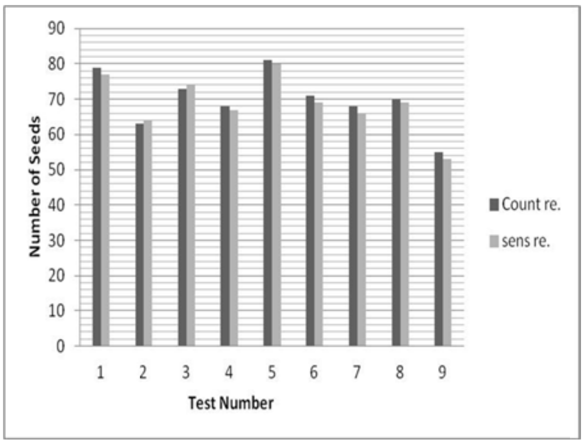

Fig (9). Counted seed numbers against sensor readings at 1.3ms^{-1} speed

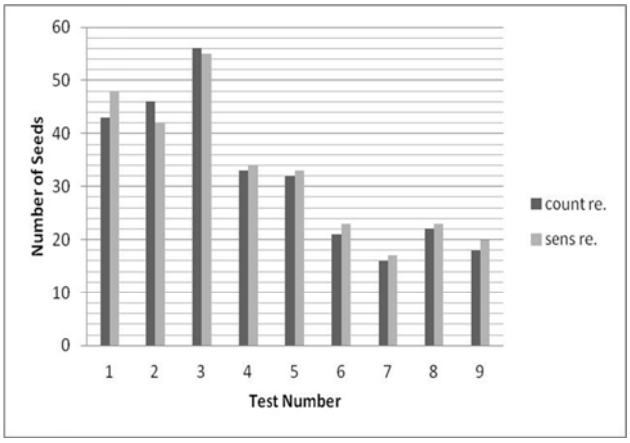

Fig (10). Counted seed numbers against sensor readings at 1.9ms^{-1} speed

3.1 Analysis of performance characteristics

Knowing the number of seeds and the elapsed time, the collected results were transferred to seed spacing's (i.e. the spacing's between the dropped seeds). This seed spacing's, however, were not final seed spacing's as seed spacing measured with the optoelectronic system did not include the effects of seed bounce and roll. A more explicit description of the seed spacing reported in this research would be spacing's between points where seed first impact the furrow after being released by the planter. But still useful to screen out planter or planter units with poor uniformity of seed metering and it could be useful in determining areas for improvement of planter or planter units.

3.2 Sensor Reading and Actual Number of Seed

The optoelectronic sensor system output data were strongly correlated with the data obtained from the manual method. The resulting average correlation coefficient was 99.3 %. This indicates that the optoelectronic sensor system can be used to monitor and to predict planter performance precisely. The analysis of variance confirmed that the model is very significant (P.V<0.01). It is obvious that both the actual number of seeds and optoelectronic sensor system measured seeds have been almost the same. In static tests, system output was linearly related to manual test result. The linear relationship was very strong as indicated by their regression equation:

$$y = 1.045x - 2.219 \quad (2)$$

Where, y is the actual number of seeds dropped and x is the number of seeds counted by the optoelectronic sensor system.

Table 1 provides comparison of test results derived from the system and from a manual measurement with the forward speeds of 1.3m/s and 1.9m/s respectively. Each speed has different gear combination setup and each group of seed was tested three times by the system to help validate the consistency of the result. For interpretation of the system number of seeds variation with forward speed, ANOVA statistical analysis was applied to the collected observation for both speeds. The ANOVA results showed that, significant differences between the numbers of seeds based on the operating speeds were observed.

The developed monitoring system could be used efficiently for the seed monitoring application. For further interpretation of the collected observations for the seed monitoring application, the system measured output error based on the manual counted number of seeds under the two operating speeds (1.3m/s and 1.9m/s) are calculated and evaluated. The amounts of the measured output errors for both the under and over amount are shown in Fig. 11. From this Figure, it is obvious that the overall system errors are within the range of ±4% for the 1.3m/s speed and ± 10% for the 1.9m/s speed.

Table (1). Manual and sensor readings at forward speed of 1.3ms^{-1} and 1.9ms^{-1}

Gear Combination.	Speed (1.3 ms^{-1})		Speed (1.9 ms^{-1})	
	Manual Readings (No. of seeds)	Sensor Reading (No. of seeds)	Manual Readings (No. of seeds)	Sensor Reading (No. of seeds)
G1	79	77	43	48
	63	64	46	42
	73	74	56	55
G2	68	67	33	34
	81	80	32	33
	71	69	21	23
G3	68	66	16	17
	70	69	22	23
	55	53	18	20

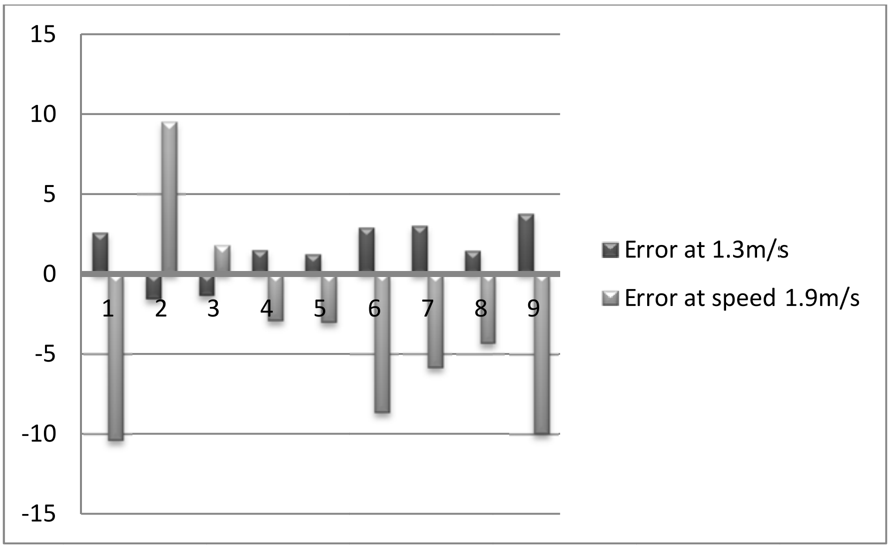

Fig (12). Output errors for seeds dropped counted by the system

Based on the performance of the developed system, the system allowed planter performance characteristics to be assessed and evaluated quickly. Also, the result of this research work indicated that laboratory testing with the optoelectronic sensor system could be useful in determining areas for improvement of planters or planting units.

4. CONCLUSIONS

An opto-electronic monitoring system for assessment of seed metering unit performance was successfully designed and developed. The developed system is comprised of an optoelectronic sensor for seed detection, encoder for forward speed and seed position measurement, amplifiers for adjusting sensors signals, microcontroller for synchronizing sensors signals, and a host computer for operating the program and displaying process. The developed system could be used for monitoring seed flow and measuring seed spacing quickly and precisely. The developed system seed flow monitoring output data from manual had a coefficient of determination r^2 of 99.3 %, indicating strong linear relationship ($y = 1.045x - 2.219$). Therefore, the developed monitoring system can be used to monitor and to predict seed flow of planter precisely. The developed system seed flow measurements results indicated that the developed system can be accurately used to measure seeds flow from the metering system with overall errors of ±4% and ± 10% for speeds of 1.3m/s and 1.9m/s, respectively, compared to manual measurements. Therefore the developed monitoring system can be used to measure and predict seed flow of planter precisely.

REFRENCES

[1] Kocher, M.F., Y. Lan, C. Chen, and J.A. Smith. 1998. Opto-electronic sensor system for rapid evaluation of planter seed spacing uniformity. *TRANSACTIONS of the ASAE* 41(1):237-245.

[2] Griepentrog, H. W. 1998. Seed distribution over the area. *EurAgEng.* 98-A-059, Oslo.

[3] Karayel, D., and A. Ozmerzi. 2002. Effect of tillage methods on sowing uniformity of maize. *Canadian Biosystems Engineering*.44: 2.23-2.26.

[4] Robinson, R.G., J.H. Ford, W.E. Lueschen, D.L. Rabas, L.J. Smith, D.D. Warnes, and J.V. Wiersma. 1981. Response of sunflower to uniformity of plant spacing. *Agron. J.* 74:363-365.

[5] Robinson, R.G., J.H. Ford, W.E. Lueschen, D.L. Rabas, L.J. Smith, D.D. Warnes, and J.V. Wiersma. 1980. Response of sunflower to plant population. *Agron. J.* 72:869- 871.

[6] Johnson, B.L, M.E. Zarnstorff, and J.F. Miller. 1999. Effect of row spacing and plant population on oil seed sunflower. Proceedings of 21 Sunflower Research Worksst hop, pgs 183-192, as found on the NDSU Extension Service web site**.**

[7] Mollanen, C.W, V.L. Hofman, and R. Eichhorst. 1987. Sunflower seed spacing uniformity tests. ASABE paper no. NCR 87-604. *ASABE, St. Joseph, MI.*

[8] Allen, R.R., L.D. Hollingsworth, and J.D. Thomas. 1983. Sunflower planting and emergence with coated seed. *TRANSACTIONS of the ASAE* 26(3):665-672.

[9] Panning, J.W., Kocher, M.F., Smith, J.A., Kachman, S.D., (2000) Laboratory and field testing of seed spacing uniformity for sugar beet Planters. *Appl. Eng. Agric*. 16 (1), 7–13.

[10] Y. Lan; M. F. Kocher; J. A. Smith (1999) Opto-electronic Sensor System for Laboratory Measurement of Planter Seed Spacing with Small Seeds. J. Agric. Engng Res. (1999) 72, 119-127 Article No. jaer.1998.0353, available online at http://www.idealibrary.com

[11] G. E. Schenkenberg, Racine, Wis. (1970), Seed Monitoring System. US patent 3,537,091, Available online at http://www.freepatentsonline.com. Accessed on 2 January 2010.

[12] Fathauer G. H., Mesa, Ariz (1979)**,** Wireless Seed Detecting and Monitoring Apparatus. US patent 41,

149, 163, Available online at http://www.freepatentsonline.com. Accessed on 2 January 2010.

[13] O'Neall D. L. and Richard T. Borovec (1997), Planter Monitor .US patent 5, 621, 666, Available online at http://www.freepatentsonline.com.Accessed on 2 January 2010.