https://pub.isae.in

Journal of Agricultural Engineering (India)

Vol. 59 (3): July-September, 2022

doi: 10.52151/jae2022593.1777

Development of a Sensor System for Detection of Missing Seeds in a Tractor-operated Groundnut Planter

Monalisa Pati[1], Aswini Kumar Goel[2], Debaraj Behera[3] and Prasant Kumar Barik[4]

[1]Senior Research Fellow, AICRP on Ergonomics and Safety in Agriculture, ICAR- Central Institute for Women in Agriculture, Bhubaneswar, Odisha, India; [2]Professor, [3]Professor and Head, Department of Farm Machinery and Power; [4]Assistant Professor, Department of Mechanical and Electrical Engineering, College of Agricultural Engineering and Technology, Odisha University of Agriculture & Technology, Bhubaneswar, Odisha, India. *Corresponding author email address: monalisa1994pati@gmail.com

Article Info

Manuscript received:
June, 2022
Revised manuscript accepted:
September, 2022

***Keywords*:** Groundnut planter, missing seeds, seed rate, sensor system

ABSTRACT

To minimize the missing seeds in groundnut planting, an Infra Red (IR) technology based sensor system was developed for a tractor drawn 9- row groundnut planter. This system could detect the number of groundnut seeds falling through a seed tube and provides visual and audible indications of missing drop(s). Laboratory evaluation of the planter with sensor system indicated that the variations of actual number of seeds dropped and display reading varied from 4.97% to 6.72% when operating speed varied from 2.5 km.h^{-1} to 3.5 km.h^{-1}. The seed rates were 118.53 kg.ha^{-1} at 2.5 km.h^{-1}, 100.10 kg.ha^{-1} at 3.0 km.h^{-1} and 93.20 kg.ha^{-1} at 3.5 km.h^{-1} operating speed. Under field condition, the planter without sensor system had lowest (22.60%) missing seeds at speed of 2.5 km.h^{-1}, and highest (32.85%) missing seeds at higher speed of 3.5 km.h^{-1}; while the planter with sensor system had 5.92% - 10.84% missing seeds with forward speed varying from 2.5 km.h^{-1} to 3.5 km.h^{1}. The missing index of seed thus, reduced by 16-22% with incorporation of the sensor device with the planter. With increase in forward speed, seed rate decreased irrespective of use of the sensor with the planter due to higher planter vibration as well as the seeds dropping back from the metering cells in the seed box before being discharged in seed tube. However, using the sensor system, no significant effect of speed on seed rate was observed.

Approximately 9% mechanization has been achieved in seeding and planting in Odisha state (Behera and Goel, 2016). Lower acceptance of seeding and planting machines are mainly due to higher cost of operation, lower plant population due to seed missing and requirement of proper soil pulverization. A tractor drawn planter is usually hitched with the three-point linkage of the tractor, which is positioned behind the tractor operator; the operator remains unable to monitor accuracy of seeds dropped from the outlet of metering mechanism into the furrows. Sometimes, wide gap remains in a row without dropping of seeds after operation of a planter. A single row manually operated groundnut planter was developed and evaluated under actual field condition, and the maximum seed missing index was 4.6% at a forward speed of 2.1 km.h^{-1} (Madhusudan and Preetham, 2020).

While operating a planter, missing of seeds in the furrow occurs due to either no flow of seeds from seed metering system or a seed tube is chocked (Kumar and Raheman, 2018). The desired plant population for getting more yields is possible if the operator gets real-time information on seed movements into the furrow through a system that can indicate, or alerts the operator, in visual/audible form.

Many researchers have tried to detect the flow of seeds in delivery tube of a planter by using detection technologies such as visual LED sensors, capacitive type sensors, microwave sensor, piezoelectric sensor, ultrasonic sensor, and image processing techniques. Among these, IR technology was found better because of high accuracy, smaller size, less power consumption, low cost, and easier control of input/output signals (Kumar and Raheman, 2018). Keeping this in view, a sensor system with IR technology was developed and evaluated for a groundnut planter.

MATERIALS AND METHODS

Development of Sensor System

Technical requirements of sensor system

Different varieties (Kadri-6, ICGV-00351, ICGV-03043) of groundnut seeds mostly used by the farmers of Odisha state for sowing were collected from Dryland Agriculture Farm (orchard), Odisha University of Agriculture and Technology, Bhubaneswar. The kernels removed from collected pods were sun-dried for 7 days to achieve moisture content within 6-8% (Ntare *et al*., 2008). The length, width, thickness, weight, volume, and sphericity were the important physical properties of the seed that affect the movement of seeds through the narrow passage of a discharge tube with IR sensors. The length and width of the popular varieties were found to be 12.61 -13.95 mm, and 6.62-7.91 mm, respectively; while sphericity was in the range of 0.57-0.61. To have better interference with the infrared light, the larger sized seed (width: 6.83 mm) of ICGV-00351 were used for laboratory and field calibration and performance evaluation.

Components

The developed system was divided into following components:

- Seed detector circuit
- Microcontroller
- LCD Interface
- Buzzer
- LED Indicator
- Power supply

The above components were fixed on a plywood board of dimension 600×300×30 mm, and wires from the above components were connected to the IR sensors of each tube. The tubes were tightly inserted on the tubular seed outlet sleeves of the seed box of a 9-row groundnut planter.

Seed detector circuit

The seed detector circuit used in the sensor system consisted of IR LEDs, photodiodes, Operational Amplifier Low power dual voltage comparator (Op-amp LM393) and mono stable multi-vibrator circuit with 555 timer. Two IR LEDs for transmission of IR signals and two photodiodes to receive the IR signals were fitted inside a hard Polyvinyl chloride (PVC) cylindrical tube of 42.25 mm inner diameter and 47.75 mm outer diameter at upper portion for assembling with a seeding outlet of the seed box. The inner diameter of each PVC cylindrical tube having length of 95 mm was reduced to 23.42 mm at its lower portion (40 mm below from the top of the PVC tube) to fit with the upper portion of vertically installed seed tube. The sensors were fitted inside the reduced portion 80 mm below from the top of PVC cylindrical tube. Groundnut seeds were metered by cell-type metering system, and the seed discharge was controlled by lowering and raising the seed outlet attached with the seed box.

Design of IR transmitter section

The IR LED is a light emitting diode which emits a particular characteristic signal having frequency in the range of infrared. Two IR LEDs of 990 nm were connected in parallel to increase the intensity and avoid data corruption. Its driver circuit was designed on the basis of current required to glow the IR LED. This section converted the electrical pulses into IR pulses, which were the output of IR LED driver section. The IR section consisted of a transistor switch, which provided approximately 25-30 mA of DC current in that IR diode. The train of light pulses from the diode was transmitted in air invisible but directional in nature.

IR Receiver Section

IR receiver section consisted of two light sensitive photodiodes with a junction of the photodiodes that generated carriers when lights fell on them. The liberation of carriers was very small in magnitude and dependent on the frequency and intensity of the light signal falling on the junction. Under the forward biased condition, the majority carrier current was so high that the current generated due to fall of light signal was negligible. The photodiodes were connected in the reverse biased condition along with a series-connected load resistor. In the reverse biased condition, the normal current was always in the order of few microamperes, the current generated due to fall of light signal on the junction was also in the order of microampere so the net current through the diode was appreciably increased.

Voltage comparator

A voltage comparator is a device that compares two voltages, and gives an output in the form of digital signal, indicating the larger one. It has two analog input terminals (V+) and (V-) and one binary digital output (V0). It gives output of either 1(when voltage at positive side as shown in terminal '3' of Fig. 1 is greater than negative side in terminal '2'), or 0 (when voltage at positive side as shown in terminal '3' of Fig. 1 is lower than negative side in terminal '2').

The output of the photodiodes was an analog signal that could not be fed directly to the microcontroller. The signal was required to be converted to a digital signal, for which an Op-amp LM393 was used and configured as a high gain amplifier or a voltage comparator. The LM393 is a low power dual voltage comparator, and also acted as dual differential comparator. The Op-amp compared one analog voltage level with another analog voltage level, or some pre-set reference voltage, and produced output signal. The voltage comparator has one non-inverting (+) terminal and one inverting (-) terminal. The reference voltage was set at inverting (-) terminal of the operational amplifier. A 10 KΩ variable resistor was connected between +5 V and ground, and the variable terminal was connected to the Op-amp for providing the threshold value.

Mono stable multi-vibrator circuit with 555 timers

The main aspect was to generate a pulse of around less than 1ms, for which IC NE555 timer was used. It was configured as a mono-stable multi-vibrator where the output signal from the comparator was not compatible to the microcontroller as it could read the input signal of 1ms duration. The duration of the generated pulse in this circuit was determined by the RC network connected externally to the 555 timers. The timer also performed as a one-shot multi-vibrator requiring an external triggering force to change the state of the output. The two comparators produced an output voltage dependent upon the voltage difference at their inputs and determined by the charging and discharging action of the externally connected RC network. The outputs from both comparators are connected to the two inputs of the flip-flop which in turn produces either a "HIGH" or "LOW" level output.

Circuit Operation

The circuit operated in two modes of (a) when a seed dropped in the tube, and (b) when a seed was missed in the tube.

Mode-1

When a seed started falling through the tube, the path between the IR LEDs and photodiodes got interrupted as infrared light from the IR LED could not directly charged the photodiode circuit, resulting to low output voltage from this circuit transmitted to the non-inverting terminal (+). Hence, the output voltage of the comparator was low as the voltage at inverting terminal (-) was greater than the voltage at non-inverting terminal. The yellow LED remained in the OFF position. Moreover, the output was low in mono stable multi-vibrator circuit when the circuit was in a stable state, transistor Q1 was ON, and capacitor C1 was shorted to ground. However, upon application of a (-) ve trigger pulse to pin-2, transistor Q1 was turned OFF and the short circuit across the external capacitor C1 was released. As a result, the output voltage became high. Due to high output voltage, the red LED connected to the output circuit remained ON up to the time period during which the output voltage was high. The capacitor C2 now started charging up

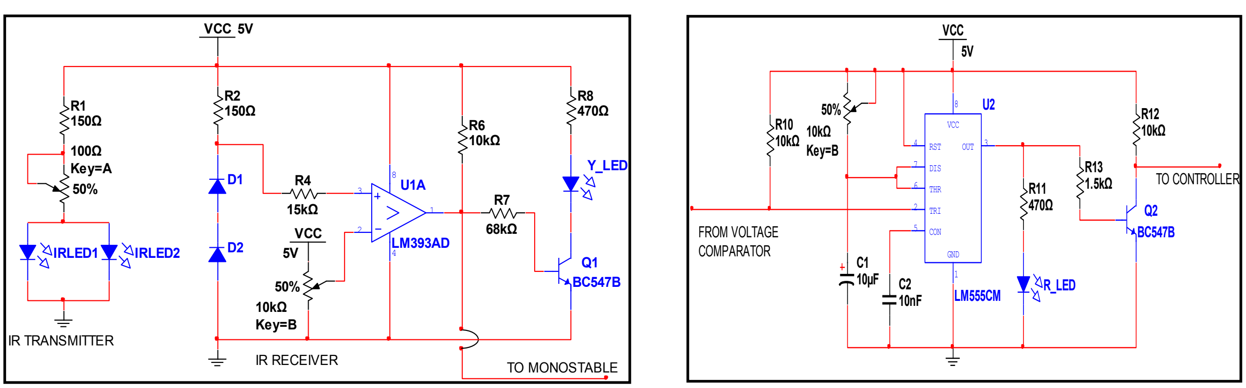


Fig. 1: Seed detector circuit for single row of groundnut planter

towards VCC (Voltage at Common Collector). When the voltage across the capacitor equalled 2/3 of VCC, the output became low. The Capacitor C2 rapidly discharged to the transistor (Fig. 1). The output voltage of the mono stable remained low until a trigger pulse was again applied.

Mode-2

When a seed did not fall through the tube, the light from IR LEDs directly fell on the respective photodiodes and photodiode circuit got charged causing the output voltage from this circuit to be high at the non-inverting terminal (+). Reference voltage (4.8 V) was given to the inverting terminal (-) through a 10 k variable resistor. As a result, the output of the comparator became high turning the yellow LED to ON position.

Likewise, 9 seed detector circuits were developed for each of the 9 rows of the 9-tyne groundnut planter used in the experiment. The output of detector circuit from each row was fed into the microcontroller.

Microcontroller

The outputs of the sensors at each row were fed to an Arduino UNO microcontroller board. Based on these output signals of the sensors and programming code, the microcontroller provided the output signal which would simultaneously activate the visual (LEDs) and audible (buzzer) alerts**.** Arduino Mega 2560 (ATmega2560) microcontroller was used in the developed sensor system. It is an 8-bit microcontroller with advanced Reduced Instruction Set Computer (RISC) architecture with high performance and low power.

LCD Interface

An alphanumeric LCD display was used in the system, which showed 4 lines and 16 characters. It worked on 5V, and had a green backlight which could be switched on and off as desired. The number of seeds dropped through the sensor fitted tube in each row, and a row at which the seeds were missing was displayed on the LCD interface according to the instructions of the microcontroller.

Buzzer

The buzzer (Bike horn of Bajaj Pulsar 150) gives indication in the form of sound of about 108 dB when there was no dropping of seeds from any row of the planter up to the timing 2 s, 1.6 s, and 1.4 s which was set according to the forward speed of operation at 2.5 $km.h^{-1}$, 3 $km.h^{-1}$, and 3.5 $km.h^{-1}$, respectively of the planter as instructed by the microcontroller.

LED Indicator

Mainly, 3 different coloured LEDs (green, yellow, red) of wavelength ranging from 500- 760 nm made up of Gallium phosphide (GaP) were used in the developed system. Hence, 9 LEDs were fitted for 9 rows of the planter. On an occasion of missing of seed in a row within the set time period i.e. 2 s for operating speed of 2.5 $km.h^{-1}$, 1.6 s for 3 $km.h^{-1}$, and 1.4 s for 3.5 $km.h^{-1}$, corresponding LED would glow as instructed by the microcontroller.

Power supply

A lead acid battery (12V, 7.2Ah) was used for Direct Current (DC) power supply to the sensor system (Fig. 2).

Components of 9-row Groundnut Planter

One 9-row groundnut planter (Table 1) with following components was used for this experiment. The major dimentions of the planter is reported in Table 1.

Table 1. Dimensions of groundnut planter

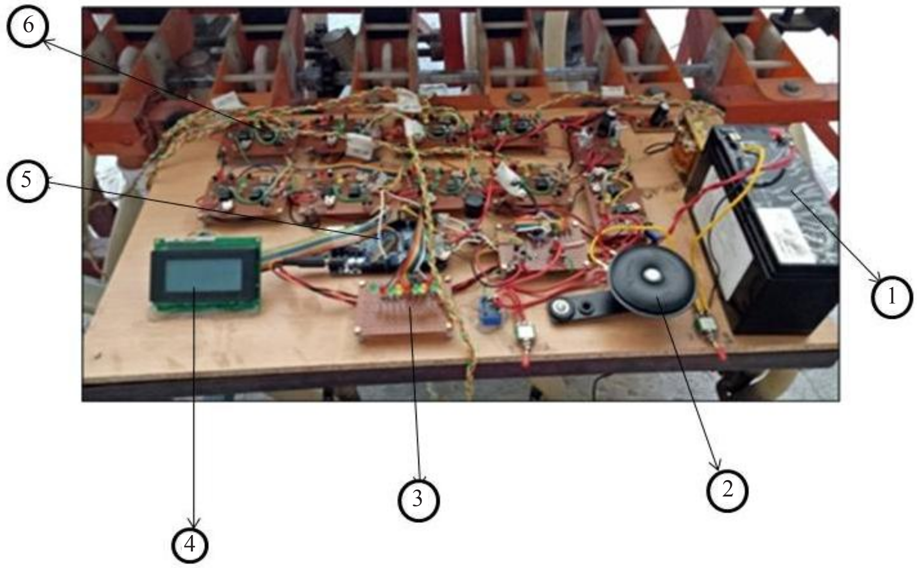
Sl. No.	Parameter	Value
1.	Length, mm	2160
2.	Width, mm	1880
3.	Height, mm	1370
4.	Weight, kg	320
5.	Metering system	Cell type

The planter used a PVC cell-feed roller type seed metering device. It had 4 cells for groundnut seed metering as shown in Fig. 3. The metering device was powered by the ground wheel (300 mm in diameter) through chain and sprocket mechansism. The ground wheel had 12 pegs made of MS flat (40×5 mm). The height of the pegs was 135 mm with triangular tip.

Plastic seed tubes (40 mm diameter, 2mm wall thickness) were used in the planter for seed discharge to the furrow openers. Reversible shovel type furrow openers made of high carbon steel were used in the planter.

Laboratory set-up

The experiment was conducted in Farm Implement Design Unit (FIDU) laboratory in the College of Agricultural Engineering and Technology (CAET),



1. 12 V Battery, 2. Buzzer, 3. LED Indicators, 4. LCD Interface, 5. Microcontroller,
6. Seed detector circuit for single row of 9 row groundnut planter

Fig. 2: Complete set-up of developed sensor system

Fig. 3: Cell type roller

Odisha University of Agriculture and Technology (OUAT), Bhubaneswar.

A rectangular frame of mild steel (MS) angle (30×30×3 mm) was constructed with frame length of 610 mm and width of 310 mm welded on the seed box frame that connected the 9 seed boxes. The board containing the sensor system, including the battery, was rigidly fixed on the fabricated frame (Fig. 2). The wires from the sensor unit were connected to the IR sensor of each tube, and the tubes were tightly inserted on the tubular seed outlet sleeves of the seed box. Groundnut seeds were filled up to 3/4th capacity of the hopper. The 9 rows of the planter were serially named from A to I.

In this experiment, 3 levels of operating speed (2.5, 3, 3.5 km.h^{-1}) were considered. The planter was kept in stationary position with the ground wheel lifted above the ground. From each speed, the time required for one revolution of the ground wheel having diameter 30 cm for each speed were calculated, and the ground wheel was manually revolved once within that time period. Ten revolutions of the ground wheel were thus made at 20 s for operating speed of 2.5 km.h^{-1}, 16 s for 3 km.h^{-1}, and 14 s for 3.5 km.h^{-1}. The gear ratio between the driving wheel (ground wheel) and the driven wheel (cup roller shaft) of cell type metering mechanism was 1:1.5; thus, 10 revolutions of the ground wheel would rotate the cell rollers 15 times in one minute. With power supply from a 12V battery to the sensor system, seed fall through the seed tubes fitted with sensors were displayed on the LCD interface with its corresponding row name. Polythene bags were tied at the end of seed tube (Fig. 4) for collecting the actual number of seeds dropped through each row. Thus, the variations between actual number of seeds dropped and that displayed reading was calculated.

Field Evaluation

The tractor was operated at 3 speeds (2.5, 3, 3.5 km.h^{-1}). As per IS Code 6316 row length of 100 m is to be taken and 5 observations are to be taken in each row i.e. minimum 20 m distance. Each reading was taken for the distance of 20.5 m for without using and with using the sensor device at a particular speed. Five

Fig. 4: Laboratory Evaluation

observations were taken for each case with respective speeds. The observations were noted and the results were computed accordingly.

Design of Experiment

The experiment was statistically designed as a randomized two-factor design with 5 replications. Missing index of seeds and seed rate were calculated and analysed. Variables considered are mentioned in Table 2.

Measurement of Dependent Parameters

Seed rate

Table 2. Design of experimental parameters

Sl. No.	Variable	No. of levels	Level values
	Independent		
1.	Forward speed, $km.h^{-1}$	3	2.5 (1) 3.0(2) 3.5 (3)
2.	Use of sensor	2	Sensor not used(1) Sensor used(2)
	Dependent/Observed		
1.	Missing index,%		
2.	Seed rate, $kg.ha^{-1}$		

The weight of the collected seeds from each row was measured by using an electronic balance (Make: Anamed, capacity: 300 g, accuracy: 0.01g). The theoretical area covered by the ground wheel in 10 revolutions was calculated.

Seed rate, $kg.ha^{-1}$ =

$$\frac{\text{Total weight of seeds collected from 9 row, kg}}{(\text{Distance covered by ground wheel in 10 revolutions} \times \text{nominal width of planter})m^2} \times 10000 \quad ...(1)$$

Missing index

The missing percentage of seed is represented by the missing index. For calculation of missing index of seeds, distance of 5 m was chosen randomly from each row after each speed of operation of the 9-row groundnut planter under both conditions of using and not using the sensor system under field condition.

It was measured by counting the number of seeds missed in a row of 5 m length to the actual number of seed s that could be dropped in 5 m row (Madhusudan and Preetham, 2020).

$$\text{Missing index (\%)} = \left[\frac{n_1}{n_2}\right] \times 100 \quad ...(2)$$

Where,

n_1 = Number of seeds missed in a row in 5 m distance, and

n_2 = Actual number of seeds could be dropped in a row in 5 m distance.

RESULTS AND DISCUSSION

The laboratory and field evaluation of the tractor-operated 9-row groundnut planter with seed discharge sensor system were essentially undertaken to evaluate the performance of the sensor system.

Before evaluation of performance of the planter with the sensor system, 30 kg groundnut seed (ICGV- 00351) was first graded (width 5.93- 6.84 mm) to fit the size of cells (10 mm) of the metering system.

Laboratory Evaluation

During laboratory evaluation, it was found that the variation between actual number of seeds dropped and display reading varied from 4.97% to 6.72% at 3 levels of speed (Fig. 5). The variation increased with increase in forward speed. Hence, the developed sensor system detected the number of seeds with low percentage of variation at all 3 operating speeds. The seed rate varied from 93.20-118.53 kg.ha^{-1} (Fig. 6) as against calibrated seed rate of 155.6 kg.ha^{-1}.

Missing seed, warning signal

The working of buzzer sound and LED indicators were observed at 3 operating speeds (2.5, 3.0, 3.5 km.h^{-1}) in 10 revolutions of ground wheel in laboratory.

At operating speed of 2.5 km.h^{-1}, there was only 1 or 2 missed seeds from some rows. This system worked with 93% accuracy. The buzzer sound and glowing of LEDs were not observed within 2s (time set for the forward speed). Buzzer sound setting was done for missing of consecutive 6 seeds (one rotation of metering cell). Hence, lower number of missing seeds (<6 seeds) in different rows did not trigger the alarm.

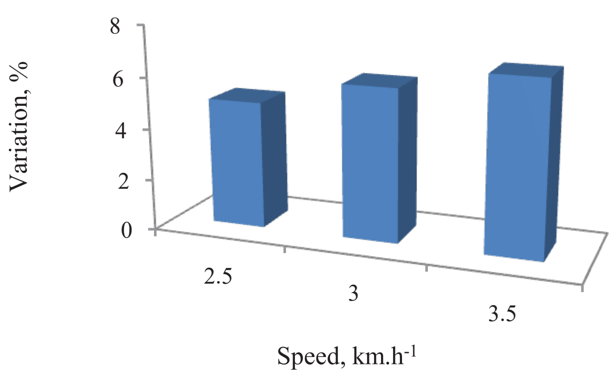


Fig. 5: Effect of forward speed on variations between actual number of seeds dropped and displayed by sensor system

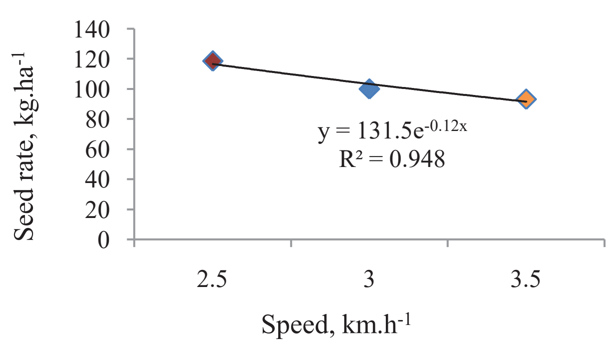


Fig. 6: Effect of forward speed on seed rate discharge under laboratory evaluation

At operating speed of 3 km.h^{-1}, buzzer sound and glowing of LED of corresponding rows were observed, indicating missing of seeds in corresponding individual rows. When the cell type roller shaft was given 10 revolutions in 16 s, 7 seeds were missed from row 4 causing the LED corresponding to the row glowed and the buzzer sound was made with the display reading for the row remaining constant.

Similarly, when 10 revolutions were completed in 15.55 s, 8 and 6 seeds were missed from the 2nd and 5th row. With 10 revolutions of cell type roller completed in 15.10 s, 7 seeds were missed from both 3rd and 6th rows and 8 seeds from the 7th row along with buzzer sound and corresponding glowing of LEDs. Higher missing of seeds was observed at operating speed of 3.5 km.h^{-1}.

When 10 revolutions were completed in 14.62 s, 6 seeds were missed from the 2nd and 9th rows and 8 seeds were missed from the 4th row. Thus, LCD display for B, I, and D did not show any increment in number of seeds counted, and these row symbols were indicated at the bottom of the LCD display unit. When 10 revolutions were completed in 14.02 s, the number of missing seeds were 8, 6, and 9 from 3th, 5th, and 8th row, respectively. Similarly, when 10 revolutions were completed in 13.15 s, 9 seeds were missed from the 1st and 9th row, 8 seeds from the 3rd row, and 7 seeds from the 4th row. The LCD corresponding to these rows were displayed at the bottom (Table 3).

A sample of data display board during operation (Fig. 7) shows that the seed count from rows 6 (F), 7(G), and 9(I) were zero. Therefore, no readings were displayed on the LCD indicating missing of seeds, and hence LEDs were glowed.

In general, it was found that with increase in forward speed, seed rate decreased (118.53 - 93.20 kg.ha-^{1}). With increase in forward speed, accuracy of the developed system decreased (95.03 -93.28%), and might be due to increased vibration of the planter causing decreasing seed rate and accuracy of the system.

Field Evaluation

The planter was evaluated at the Central Farm, OUAT, Bhubaneswar in a plot size was 200 m^2 (Fig. 8). The soil was sandy loam, and the moisture content was 12.23 (%, wb) at the time of the experiment. The field was pulverised with tractor-operated rotavator (twice).

The observations as missing seeds, buzzer sound,

Table 3. Observation with respect to missing seeds, buzzer sound, and glowing of LED during laboratory evaluation

Speed of operation, km.h^{-1}	Time taken for 10 revolutions, s	No. of consecutive missed seeds per 10 revolution (≥6)	Observation	
			Buzzer sound	Glowing of LED
	20.50	-	Not observed	Not observed
2.5	20.22	-	Not observed	Not observed
	19.12	-	Not observed	Not observed
	16.00	7	Observed	No. 4 LED glowed
3.0	15.55	8/6	Observed	No. 2 & 5 LED glowed
	15.10	7/7/8	Observed	No. 3, 6 & 7 LED glowed
	14.62	6/8/6	Observed	No. 2, 4 & 9 LED glowed
3.5	14.02	8/6/9	Observed	No. 3, 5 & 8 LED glowed
	13.15	9/8/7/9	Observed	No. 1,3, 4 & 9 LED glowed

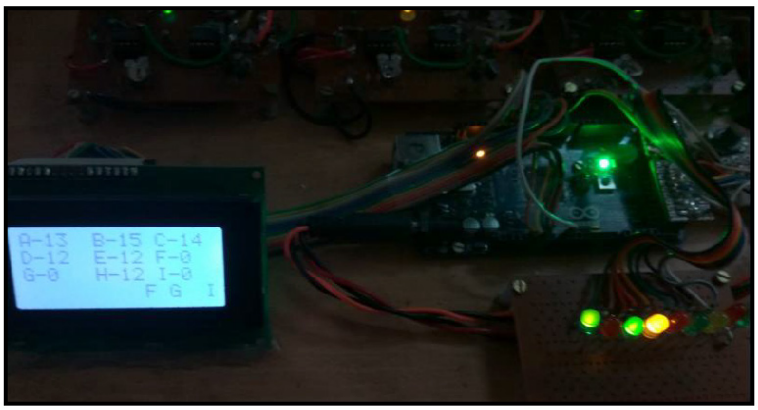


Fig. 7: Indication of missing seeds on LCD display with glowing of LED during laboratory evaluation

glowing of LED, and the effect of speed on missing index and seed rate were recorded.

Missing seed, warning signal

The seed box was filled with 3/4th of hopper capacity with 22.5 kg of graded seeds. The working of buzzer sound and LED indicators were observed (three observations for each operating speed) at 3 operating speed (2.5, 3.0, 3.5 km.h^{-1}), while the tractor was operated for a distance of 20.5 m using sensor device in position. It was observed that at operating speed of 2.5 km.h^{-1}, 7 seeds were missed from the 6th and 9th row; while 9 seeds were missed from the 8th row in first observation. During the 2nd and 3rdobservations at same operating speed, 8 seeds were missed from the 3rd, 4th and 5th row; while 10 and 9 seeds were missed from the 2nd and 7th row, respectively.

Similarly, at 3 km.h^{-1} operating speed, 9 seeds from the 2nd ,4th, and 6th row, 7 seeds from the 2nd and 4th row, 10 seeds from the 5th and 8th row, 11 seeds from the 3rd row, 12 seeds from the 9th row, and 14 seeds from the 1st row were missed in three observations.

At 3.5 km.h^{-1} operating speed, 10 seeds from the 8th and 9th row, 11 seeds from 4th and 5th row, 13 seeds from 1st and 8th row, 15 seeds from 7th row, 16 seeds from 1st and 6th row, 18 seeds from 2nd row and 20 seeds from 3rd and 7th row were missed in three observations (Table 4).

Buzzer sound, corresponding LED glow, and display of row nomenclatures at the bottom of LCD were observed during continuous missing seed drops from the rows during field operation at various operating speeds (Table 4). It was also observed that higher numbers of seeds were missed during field operation as compared to laboratory evaluation, due to vibration of the planter causing seed dropping back in seed box from metering cells during field operation.

Fig. 8: Field evaluation of planter with sensor system

Table 4. Missing seeds, buzzer sound, and glowing of LED during field evaluation

Speed of operation, km.h^{-1}	No. of (≥6) consecutive missed seeds in 20.5 m distance	Observation	
		Buzzer sound	Glowing of LED
	7/9/7	Observed	No. 6, 8 & 9 LED glowed
2.5	10/8	Observed	No. 2 & 5 LED glowed
	8/8/9	Observed	No.4,3 & 7 LED glowed
	7/9/10	Observed	No 2, 4 & 5 LED glowed
3.0	11/9/10	Observed	No. 3, 6 & 8 LED glowed
	14/9/7/12	Observed	No.1,2, 4 & 9 LED glowed
	16/11/15/10	Observed	No. 1, 5,7 & 9 glowed
3.5	18/11/16/20/10	Observed	No. 2,4,6,7 & 8 glowed
	13/20/13/16	Observed	No. 1,3,8 & 9 glowed

Effect of forward speed on missing index

The planter was operated without and with sensor system and the missing index under both conditions were compared. When the planter (without sensor system) was operated at increasing operating speeds, the missing index increased from 22.60% to 32.85%. This might be due to higher planter vibration occurring with increase in operating speed causing the seeds to drop back from the cells in the seed box before falling in seed tubes. At lower speed of operation, negligible dropping of seeds from metering cells back to the seed box took place. Lowest (22.60%) missing of seeds occurred at lowest operational speed of 2.5 km.h^{-1}; while highest missing seeds (32.85%) were observed at highest forward speed of 3.5 km.h^{-1}. When the sensor system was attached with the planter; it was observed that the missing seeds varied from 5.92% to 10.84% only. Similar trends of increase in missing seeds with increase in speed were also observed (Fig. 9).

By incorporation of sensor system with the planter the missing seeds were reduced from 22.60-32.85% to 5.92-10.84%. Hence the percentage of missing can be reduced to an extent of 16 to 22% by using sensor system in the planter. The lower missing seeds with sensor device were due to immediate rectification of the problems indicated by respective row LED glowing, buzzer sound and displaying the row number pertaining to missing.

ANOVA for missing index

The impact of using the sensor system on missing index was significant at 1% level of significance. Statistical data (Table 5) also indicated that using the sensor device reduced the seed missing index.

The mean values of missing index from interaction between operating speed and using / not using the sensor device are given in Table 5. It was found that the effect of forward speed on missing index in both cases was significant at 1% level of significance.

Effect of speed on seed rate

Seed rate is an important parameter for obtaining desired plant population. It was observed that with increase in forward speed, the seed rate decreased for both cases of planter without sensor unit and with sensor unit. The theoretical seed rate was 155.6 kg.ha^{-1}. With increase in forward speed from 2.5 km.h^{-1} to 3.5 km.h^{-1}, the seed rate decreased from 132.2 kg.ha^{-1} to 91.9 kg.ha^{-1} with the planter without sensor system, while the same ranged from 158.46 kg.ha^{-1} to 115.93 kg.ha^{-1} (average 141.15 kg.ha^{-1}) with sensor system (Fig. 10). Higher seed rate of 20-26% was observed at all 3 levels of forward speeds of the planter with sensor system due to the reason that missing of seeds was significantly lower through proper warning systems enabling the operator to take corrective measures. Hence, higher plant population can be obtained by using the planter with sensor device and 91% accuracy of seed rate could be achieved.

ANOVA for seed rate

Mean seed rates of 145.35, 136.06, and 103.94 kg.ha^{-1} were observed at operating speed of 2.5, 3.0, and 3.5 km.h^{-1}, respectively, during field operation of the planter. Therefore, the effect of forward speed on seed rate was significant at 1% level of significance (Table 6).

Highest seed rate of 145.35 kg.ha^{-1}was observed at operating speed of 2.5 km.h^{-1}. It was also evident

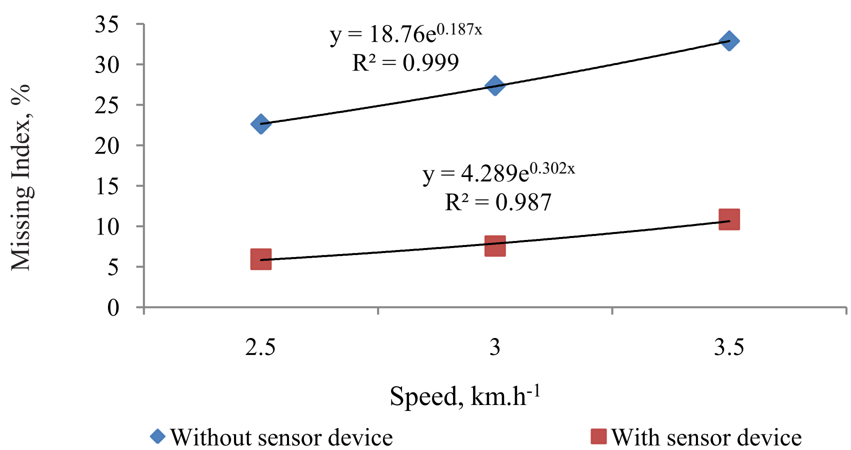


Fig. 9: Effect of speed on missing index in field condition

Table 5. ANOVA for missing index

Source	Df	SS	MS	F Value	SEM	$CD_{(0.05)}$	$CD_{(0.01)}$	Prob
Factor A	2	290.162	145.081	45.0537	0.5675	1.1713	1.5873	0.0000
Factor B	1	2848.951	2848.951	884.7170	0.4633	0.9562	1.2958	0.0000
AB	2	35.827	17.913	5.5628	0.8025	1.6562	2.2445	0.0104
Standard Error	24	77.284	3.220					
Total	29	3252.224						

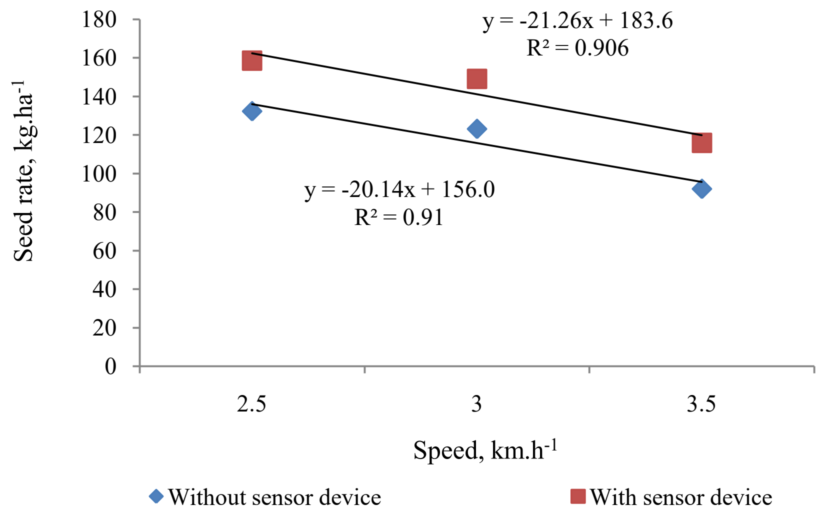


Fig. 10: Effect of speed on seed rate in field condition

Table 6. ANOVA for seed rate

Source	Df	SS	MS	F Value	SEM	$CD_{(0.05)}$	$CD_{(0.01)}$	Prob
Factor A	2	9443.383	4721.692	590.4862	0.8942	1.8455	2.501	0.0000
Factor B	1	4837.431	4837.431	604.9603	0.7301	1.5069	2.042	0.0000
AB	2	7.592	3.796	0.4747	1.2646	2.6100	3.5370	
Standard Error	24	191.911	7.996					
Total	29	14480.317						

from the data that the seed rate decreased as operating speed increased. Mean seed rate of 115.75 $kg.ha^{-1}$was observed without using sensor device, and 141.15 $kg.ha^{-1}$with use of sensor device. The effect of non-use of the sensor system and use of sensor system on seed rate was significant at 1% level of significance (Table 5). It is also evident from the data that seed rate increased with use of the sensor device. The mean values of seed rate obtained from interaction of different operating speeds without using sensor device and using sensor device are given in Table 5. It was found that the effect of forward speed on seed rate without and with using sensor device were significant at 1% level of significance. The seed rate decreased in both cases (not using and using sensor device) with increase in operating speed, and increased with use of sensor device.

The operating speed had significant effect on missing index of seeds and the actual seed rate for the planter when operated either with or without use of the sensor device. It was observed that with increase in speed, seed rate decreased irrespective of use of the sensor device. Use of the sensor system, however, increased the actual seed rate by 20 - 26% as compared to the planter used without the sensor system.

The functions of buzzer, LED indicators, and LCD display under laboratory and field conditions were observed. The results showed that all components of the sensor system worked properly, and missing of seeds were detected effectively by the system by glowing of respective LEDs, indications of missing row number on LCD interface, and emission of buzzer sound.

CONCLUSIONS

Laboratory evaluation of the planter with sensor system revealed that the variations of actual number of seeds dropped and display reading of developed system varied from 4.97% to 6.72% when operating speed varied from 2.5 $km.h^{-1}$ to 3.5 $km.h^{-1}$. The seed rates were found to be 118.53 $kg.ha^{-1}$ at 2.5 $km.h^{-1}$, 100.10 $kg.ha^{-1}$ at 3.0 $km.h^{-1}$, and 93.20 $kg.ha^{-1}$ at 3.5 $km.h^{-1}$ operating speeds. Under field condition, the planter without sensor system had lowest missing index of seed (22.60%) at lowest speed of 2.5 km.h^{-1}; and the highest missing index (32.85%)occurred at highest forward speed of 3.5 km.h^{-1}. With use of sensor system, the missing index of seed reduced up to 16-22 per cent. Use of sensor system increased the seed rate by 20 -26% as compared to the planter without sensor system due to reduction of missing seeds.

REFERENCES

Behera D; Goel A K. 2016. Farm Implements and Machinery: A reference Guide. Department of Farm Machinery and Power, CAET, OUAT, Bhubaneswar.

Kumar R; Raheman H. 2018. Detection of flow of seeds in the seed delivery tube and choking of boot of a seed drill. Comput. Electron.Agric., 153, 266–277.

Lan Y; Kocher M F; Smith J A. 1999. Opto-electronic sensor system for laboratory measurement of planter seed spacing with small seeds. J. Agric. Eng. Res., 72, 119-127.

Madhusudan B S; Preetham M N S. 2020. Design, development and performance evaluation of manually operated groundnut planter. Indian J. Ecol., 47(3), 858-862.

Ntare B R; Diallo A T; Ndjeunga J; Waliyar F. 2008. Groundnut Seed production Manual. International Crops Research Institute for the Semi- Arid Tropics (ICRISAT), Andhra Pradesh, India, pp: 20.

Raheman H; Kumar R. 2015. An embedded system for detecting seed flow in the delivery tube of a seed drill. In: Proc. International Conference on Advances in Chemical, Biological, and Environmental Engineering (ACBEE), Singapore, 236- 241. ISBN 978-93-84468-20-0.