Digital Seedling Counter for Detection of Seedling Flow and Spacing in Vegetable Transplanter: A Low Cost Solution

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International Journal of Engineering Research & Management Technology ISSN: 2348-4039
January-2016 Volume 3, Issue-1
Email: editor@ijermt.org www.ijermt.org

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ABSTRACT:
An optoelectric sensor based digital seedling counter was developed for measuringseedling spacing and for detecting the flow of seedlings through the seedling delivery tube. It was placed on the seedling delivery tube through which the seedlings were transferred to the ground from the metering mechanism. The performance of the developed sensor was evaluated both in the soil binas well as in actual field conditions. Seedling spacing was calculated with the signals obtained from optical sensor in data acquisition system (DAS) whereas seedling flow was counted by processed signals in microcontroller based digital seedling counter in soil bin conditions. The seedling spacing was calculated by measuring the output of the optical sensor over time and seedling flow was calculated writing a program in the circuit, to convert the optical sensor output to calculate number of seedling falls. Number of seedling falls was programmed to be calculated and digitally displayed on the tractor dashboard whereas seedling flow was seen in the display of oscilloscope by output signals i.e. voltage over time. The developed sensor could successfully sense the seedling fall through the delivery tube, counted it and displayed it digitally. It provided information to the operator regarding flow of plants in the tube. The seedling spacing obtained in the soil bin and field conditions varied from 0+1.5 cm and 0±3 cm, respectively for the entire range of speeds and seedlings selected. Number of seedlings counted manually and by sensor for both soil bin and field had 0% variation.

KEYWORDS: Digital seedling counter, Optoelectric sensor, Microcontroller, seedling vegetable transplanter.

1. INTRODUCTION:

After raising good quality seedlings, transplanting them in the field with uniform spacing is one of the stages in the raising vegetable crops (Labowsky, 2001; Parish, 2005). It is carried out by vegetable transplanters using various type of metering mechanisms (Brewer, 1994; Shaw, 1997). Spacing between plants is obtained by maintaining proper gear ratio between ground wheels and metering mechanism. Uniform spacing between plants provides enough space for the plant to grow and develop and reduce the nutrient uptake competition between plant and weeds by depressing the weed growth (Allen et al., 1983; Heege, 1993).Hence, evaluation of meteringmechanismis therefore essential as it is required for maintaining the recommended plant spacing and population. The conventional method for seedling spacing measurement in the field is done manually and is a very tedious process. Further, it is very difficult for the operator to see the workability of the metering mechanism of transplanter during operation in the field. Most of the studies on seed spacing evaluation were made either with a sticky belt test stand or an optoelectronic sensor system (Muller et al., 1994; Raheman and Singh 2003).Panning et al. (2000) evaluated five planter configurations for seed spacing uniformity at three operating speeds using a seed location method in the field and a laboratory method involving an opto-electronic sensor system. Kocher et al. (1998) and Lan et al. (1999) developed anopto-electronicseedplacement measuring system that measured time intervals between the seeds, and detected front and back seed drop location events to determine the seed spacing uniformity of a planter in the laboratory.Karayel et al. (2006) used a high-speed camera system to evaluate seed spacing uniformity and velocity of fall of wheat and soybean seeds. The performance of the high-speed camera system, in terms of seed spacing evaluation was compared with a sticky belt tests and,which was used as a reference. Inall the tests it was found that the high-speed camerasystemdidnotmissanyseed. Opto-electronic measurement systems reduced labour requirement for seed spacing monitoring considerably but for small seeds there was difficulty in sensing the flow of seeds. The seed spacing measurement techniques started with the use of sticky bed/belt method and progressed towards the use of high speed camera. Use of high speed camera and its signal processing seems to be costlierbutis effective for high flow of small seeds As compared to seeds, vegetable seedlings are much larger in size and flow of vegetable seedlings per unit area is much less. Hence, optoelectric sensor could be a suitable method for proper detection of its flow. In automatic vegetable transplanters, the seedlings are fed to the metering mechanism and transplanted in the field without human intervention. It is very difficult for the tractor operator to see the workability of the metering unitduring field operation. An attempt was therefore made to develop a sensor which could show the flow of seedlings and count the number of fall of seedling to help the operator as well as to maintain the desired plant population.

2. MATERIALS AND METHODS:

2.1Working of optoelectric sensor based digital seedling counter

Seedling counter assembly comprised a light sensor box and a seedling counter box with LCD display of the counter. The light sensor consisted of a light source and an optical light sensor. The signals were fed to the optical sensor box, processed and sent to the microcontroller box and then to the data acquisition system (DAS). Microcontroller box processed the input signals from the optical box and sent them to the LCD display of the counter. Voltage data were stored in the DAS and used for measurement of plant spacing. The spacing between seedlings was calculated manually and from the data obtained using sensor in soil bin conditions. Schematic diagram of the components of the digital seedling counter are shown in Fig.1.

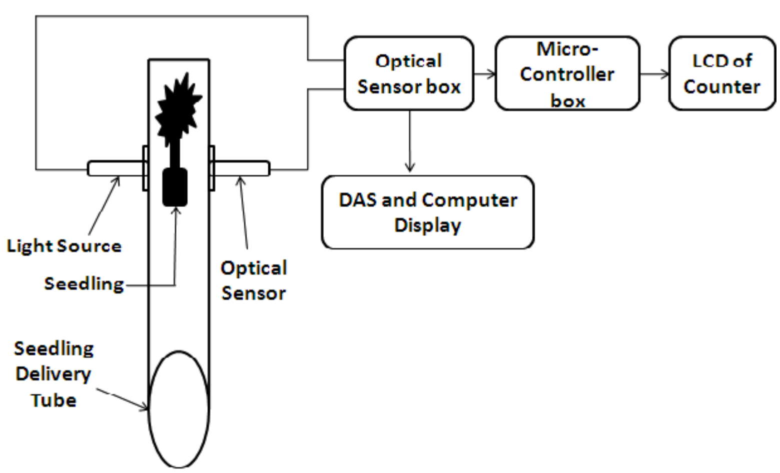


Fig. 1 Components of the digital seedling counter

2.2DEVELOPMENT OF LIGHT SENSOR AND WORKING PRINCIPLE:

The developed sensor comprised a power supply unit (12 Vbatteryor 220VAC supply), transformer, rectifier diodes, regulator IC, capacitors, light source, optical sensor, comparator and LED. Detailed drawing with component designation is shown in Fig2a. Two options were kept to supply the power to the opto-electric sensor circuit so that in the laboratory it could be operated by 220 V AC supply. Working principle of a sensor is based on light. When the power was supplied to the circuit the transformer circuit could step-down the 220 V to 12V AC supply. The rectifier circuit consisting of diodes was used for converting the AC supply to 12 V DC supply. One connection of 12 V DC was then sent to the regulator IC which reduced the

12 volt DC to 5VDCand sent to the light source. Another connection for supplying 12 V was given to the comparator from where the connection was made with light sensor. After comparator the output was measured through (J3) and the LED was placed in the circuit. When the power was supplied through either 12 V battery or 220 VAC supply, the light source emitted the light which was sensed by the optical light sensor. When the pot seedling in seedling delivery tube obstructed the light path, fluctuation of voltage occurred which were recorded by DAS over time (Fig. 2b). LED gets blinked every time when there was an obstruction on the light path. The plot of voltage verses time was used to measure the seedling spacing.

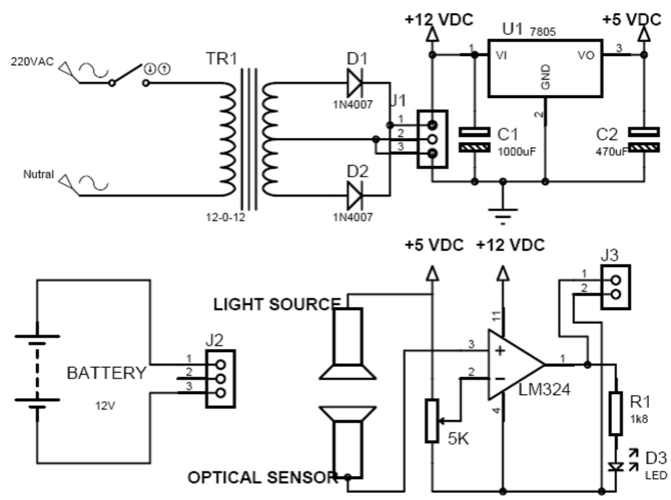


Fig. 2a Circuit digram of the developed sensor

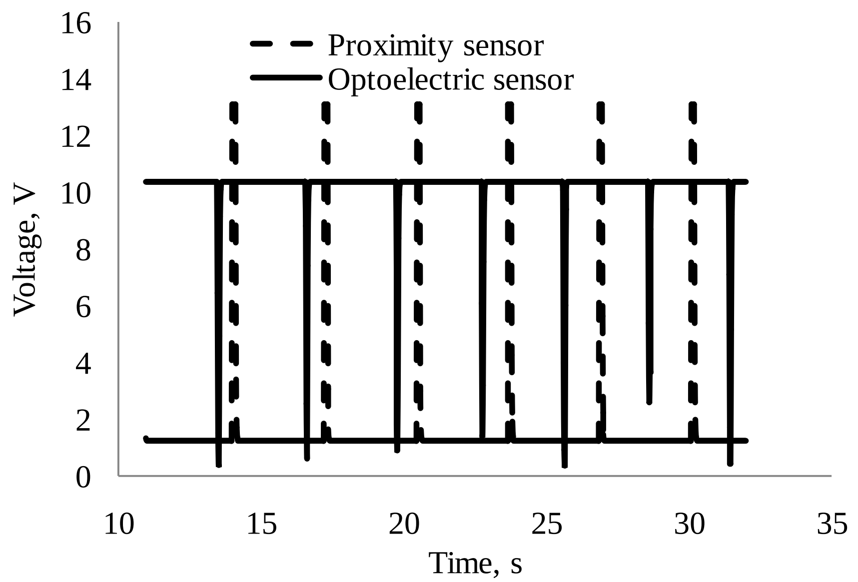


Fig. 2bSample output signals from DAS

2.3 DEVELOPMENT OF DIGITAL SEEDLING COUNTER:

Digital counter compriseda transistor, microcontroller, LCD display and RS232 port (Fig. 3). The counter was triggered by output signals from the optical sensor. These input signals were amplified with the transistor (Q1). Each pulse triggered the microcontroller (PIC16F877A) pin (RB0/INT). The microcontroller was programmed for counting the number of pulses. The program was written in C language and was compiled with Micro C for PIC (machine language). It generated the hex code for this controller and burnt with it. Each time, the pulse was coming from optical sensor on the interruption pin of the microcontroller, the program was developed in such a way that it would measure the counter value by one signal. These values were stored as a binary value and were converted with string to display the decimal value on the LCD terminal and corresponding value was available in the computer through RS232 chip (MAX232).

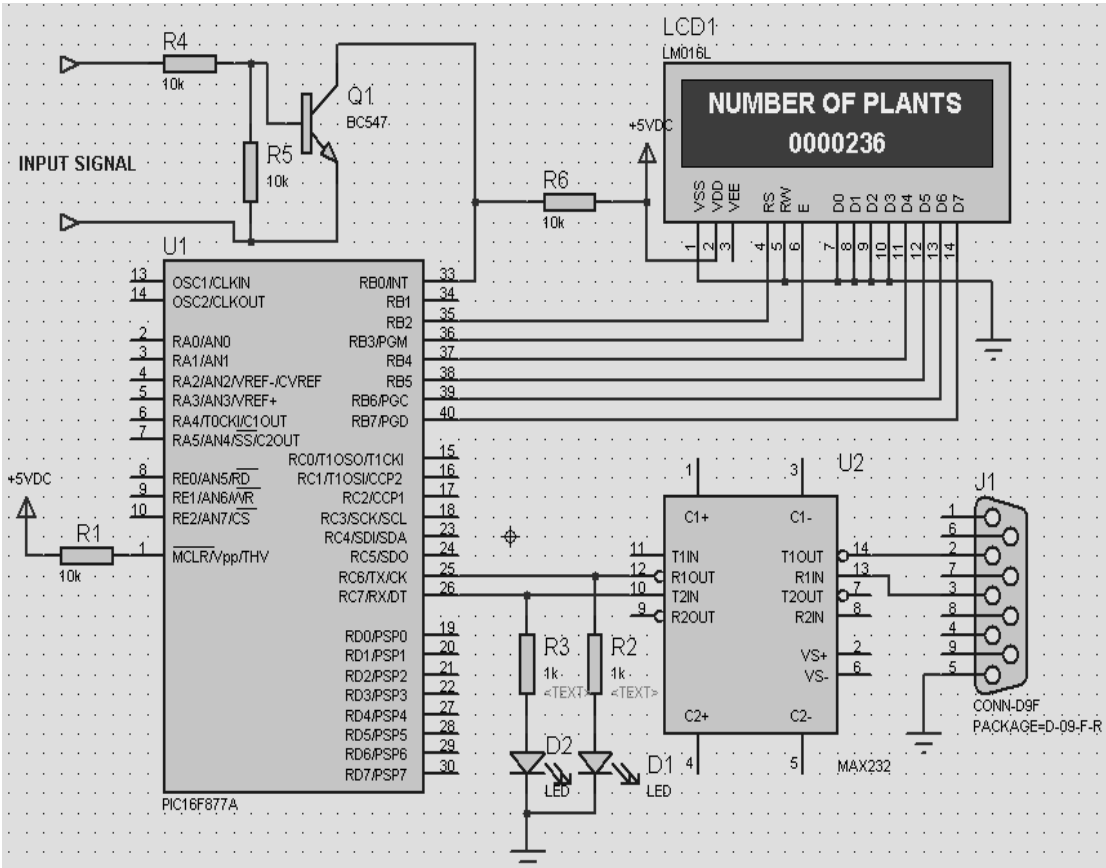


Fig. 3Circuit diagram of microcontroller based seedling counter

2.4SOIL BIN SETUP FOR EVALUATING THE SEEDLING COUNTER:

The developed experimental set-up (Fig. 4) consisted of an indoor soil bin 15 m × 1.8 m × 0.6 m, a soil processing trolley(1), an implement trolley (2), metering mechanism setup (3), Electric motor (4), digital seedling counter (6), laptop (7), DAS (8), DC speed controller (9), a control panel for linear speed transmission system (10), proximity sensor (11) and anoptoelectric sensor with both AC and DC power supply options (12).Anoptoelectric sensor was inserted in the wall of the seedling delivery tube of the developed metering mechanism setup for sensing the seedling flow and measurement of seedling spacing. The metering unit comprised conical cups where the seedlings were kept and a slotted plate was placed at the bottom of the magazine to release the seedling pots which was then moving through a delivery tube to the ground. The metering unit was powered with the help of a 2.23 kWelectric motor using a combination of gear and chain drive transmission. Rotary speed of metering unit was controlled by a DC speed controller. Forward speed of the setup was measured by proximity switch attached to the setup. The calibration of DC speed controller was carried out to synchronize the speed of metering with linear speed for obtaining plant spacings of 45cm and 60cm.

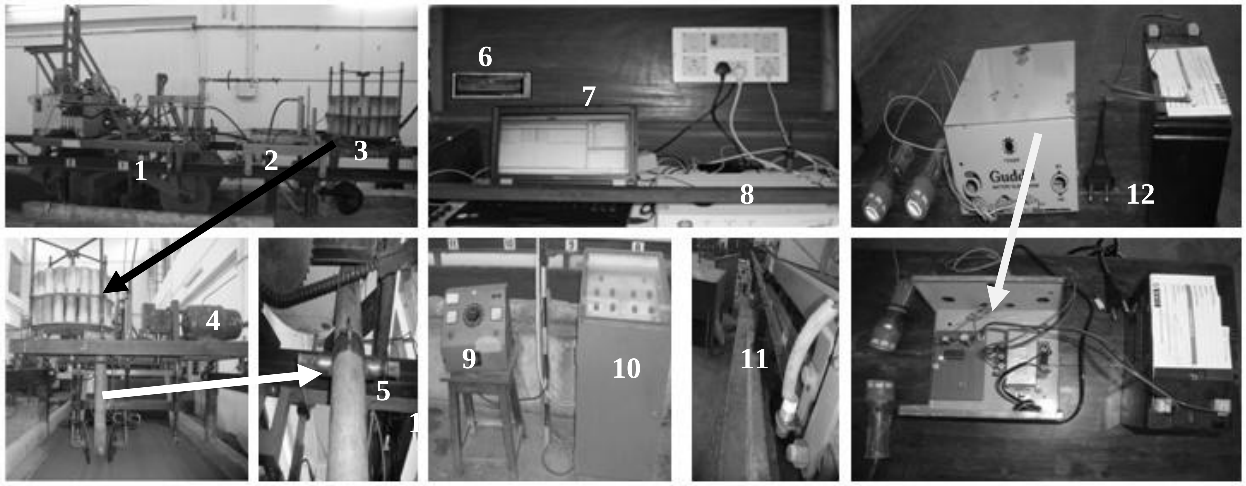


Fig. 4soil bin setup for evaluating developed seedling counter

2.4.1TEST PROCEDURE IN LABORATORY CONDITIONS:

Pot seedlings of tomato brinjal and chili were used for evaluation of the developed setup. The heights for different seedlings were in the range of 12±2 cm for tomato and 9±2 cm for both brinjal and chili. Cylindrical shaped pots were used with diameter, height and maximum diagonal length of potas50±1 mm, 40±1 mm, 64±1 mm, respectively.

Forward movement of the whole metering setup was possible with a7.46 kW electric motor coupled to a gear box having provision to change the forward speed from 0.6, 0.8, 1.2 and 2.2 km/h usinggear shifting lever. A proximity switch was used to measure the actual forward speed of operation. The simulated field conditions were maintained in the soil bin for testing of the developed sensor. Cone index of about 225±25 kPa and a bulk density of 1.2±05 kg/m^3 and moisture content of 9.5±1% (db) were maintained in the depth range of 0-80 mm of soil bed for each test. Cup type metering mechanism developed at Agricultural and Food Engineering Department, IIT Kharagpur was used for evaluation of the developed sensor. The seedlings were kept in the conical cups and rotary motion to the metering unit was given through DC speed controlled motor. Rotary speed of the metering unit was decided by inter plant spacing in the row. Two plant spacing's 45cm and 60cm were used for evaluation. Initially, all the electric connections were checked for proper working of the whole metering unit setup and optoelectric sensor circuit. 12V dc supply was given through battery to power the developed circuit. Data acquisition system and motor both were started at same time and data on plant spacing and actual speed of operation of the setup in terms of voltage were recorded. Data for four rotational speeds corresponding to four forward speeds (0.6, 0.8, 1.2and 2.2 km/h) were collected for tomato brinjal and chili plants. Sensor outputs were recorded in DAS and then were analyzed for finding the seedling spacing. The time intervals measured between the seedling falls, and front and back seedling drop location detected events were used to determine the seed spacing in the soil bin. The seedling spacing was calculated by using following formula.

Seedling spacing,(cm) $=\frac{(A-B)}{C-D}\times(E-F)$

Where,

(A-B) = Distance between front voltage peak (A) and back voltage peak (B) of the proximity sensor (cm)

(C-D)=Difference in time corresponding to front voltage peak (D) and back voltage peak (C) of the of proximity sensor (s)

(E-F)=Difference in time between front voltage peak (E) and back voltage peak (F) of the of optical sensor (s)

2.5 FIELD TESTING OF SEEDLING COUNTER:

The sensor was fixed on the wall of the delivery tube. The oscilloscope and digital seedling counter were fixed on a frame near the footrest of the tractor operator (Fig. 4). Power was supplied to the assembly by 12 V DC battery Rather than using a DAS (make: HBM, model: spider 8),a digital storage oscilloscope (Make:Tectronix, Model TDS2002, 60MHz, 1GS/s) was used to store the seedling flow data and counter was used to count the number of fall of seedlings and for its digital display. The metering mechanism of the vegetable transplanter was filled with paper pot seedlings (40 seedlings) then vegetable transplanter was lowered to the ground. The speed of rotation of the metering unit was synchronized with forward speed of tractor by fixing gear ratio based on the plant spacing. The pant spacing was changed by changing the gear ratio between ground wheels and metering unit. The tests were carried out for a range of speeds from 0.6 to 2.2 km/h. Data were collected in the field condition on seedling spacing and number of fall of seedlings both manually as well as by the sensor.

1. Seedling counter 2. Oscilloscope 3.Optoelectric sensor 4. Optical sensor box

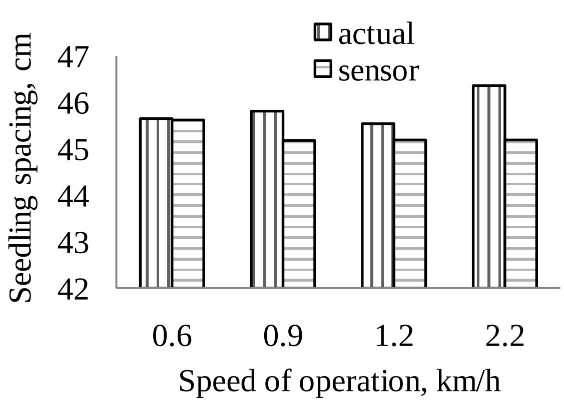
Fig. 5 Field testing using developed seedling counter

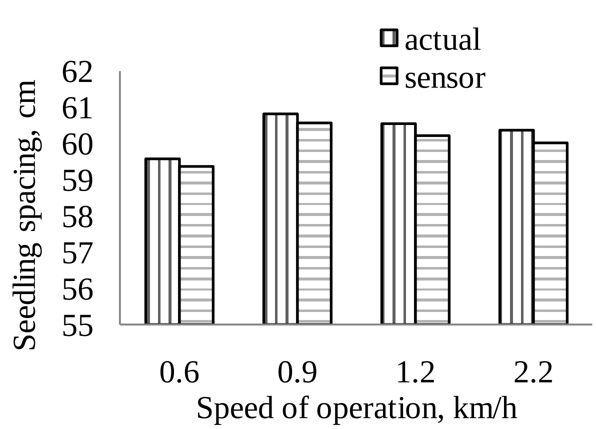
3. RESULTS AND DISCUSSION:

3.1 LABORATORY EVALUATION:

Variation was found to be within0±2 cm from the desired spacing. The data on seedling spacing collected manually and by the sensor for different seedlings at different speed of operation were compared in Fig. 6.

Tomato





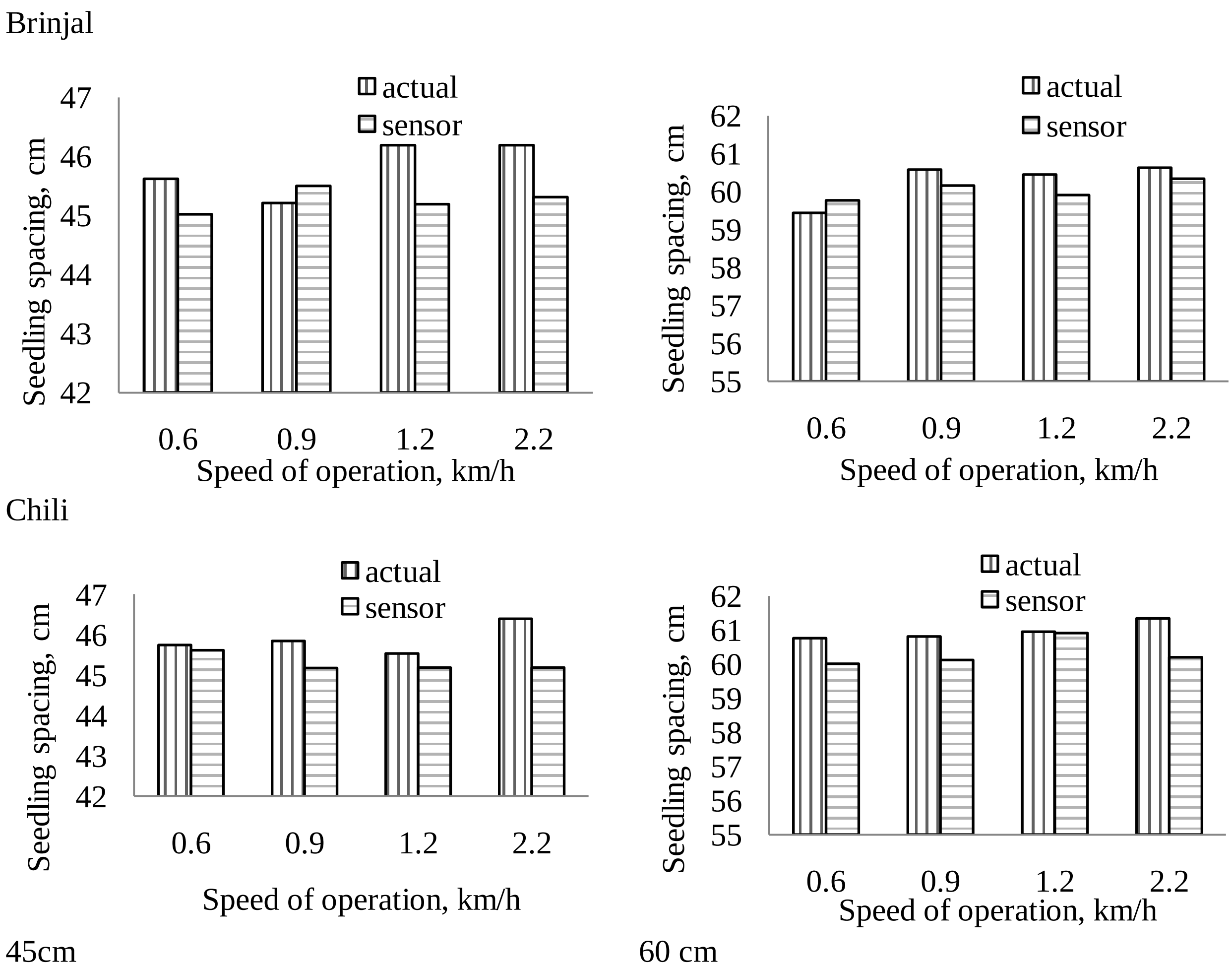


Fig. 6Seedling spacing obtained manually and by the sensor for different plants and spacing at different speeds of operation.

Seedling spacing measured actually and by sensor for all type of seedlings used for the entire range of speed in the soil bin evaluation of the sensor varied from 0.54-1.16 cm and 0.19-0.62 cm for tomato, 0.19-0.62 cm and 0.02-0.50 cm for brinjal, 0.40-0.85 cm and 0.19-0.62 cm for chili respectively at the seedling spacing setting of 45 cm. Similarly 0.36-0.81 cm and 0.01-0.56 cm for tomato, 0.44-0.63 cm and 0.16-0.47 cm for brinjal, 0.34-0.95 cm and 0.01-0.91 cm for chili respectively at the seedling spacing setting of 60 cm and found to be varying within 0 to (+) 1.5 cm for both the desired plant spacing. Data collected on number of seedlings fall in soil bin conditions actually and that shown in the counter was compared and found similar with no variation.

3.2 FIELD EVALUATION:

The data on seedling spacing collected manually and by the sensor for different seedlings at different speed of operation varied from 44.54-47.16 cm and 44.19-47.12 cm for tomato, 44.19-47.62 cm and 44.02-47.50 cm for brinjal, 43.49-47.85 cm and 44.19-47.62 cm for chili, respectively at the seedling spacing setting of 45 cm. Similarly 59.36-62.81 cm and 58.01-62.56 cm for tomato, 58.44-62.63 cm and 58.16-62.17 cm for brinjal, 59.34-62.95 cm and 58.01-62.71 cm for chili at the seedling spacing settingof 60 cm.The variations in spacing from the desired spacing was found 0±3 cm for all the seedlings. About 1 to 2% variation was observed while comparing the field data with these obtained in soil bin condition. This variation could be due the irregular field conditions. Seedling counting data observed in laboratory and field, both manually and by the sensor was found no or negligible variation. Hence the developed sensor was capable of counting the seedling falls without missing a single seedling and helps the operator to see the workability of the vegetable transplanter in actual filed condition.

4. CONCLUSIONS:

1. The developed sensor could successfully sense the seedling fall through the delivery tube, counted it and displayed it digitally. It provided information to the operator regarding flow of seedlings through seedling delivery tube.
2. The seedling spacing obtained in the soil bin and field conditions varied from 0+1.5 cm and 0±3 cm, respectively. Number of seedlings counted manually and by sensor for both soil bin and field had not missed a single seedling.
3. Seedling counting data observed in laboratory and field, both manually and by the sensor was found no or negligible variation.
4. It can be used with the automatic vegetable transplanters using paper pot seedlings and facilitates the operator to see the workability of the multistage planting units.

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