Microcontroller-based Low-cost Seed Metering Module Retrofit on Cultivator

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Planting is one of critical operations in agriculture. Ground wheel drives conventional metering mechanism, and results in improper placement of seeds because of skidding and vibration of the ground wheel. Electronically equipped seed metering system in the planter have potential to reduces losses associated with friction and wheel slippage. In this study, a retrofit type microcontroller based low-cost seed metering module was developed for commonly available cultivator. Basically, it can be called as mechatronics due to combination of both electronics and mechanical components. Seed metering plate'scell size was designed based on physical properties of black and green gram seeds. The microcontroller controlled motor's speed through Pulse Width Modulation (PWM) based on a signal obtained from a rotary encoder mounted on ground wheel. Under laboratory test, the developed module with a cell size of 5.5 mm found highest quality of feed index of 90 % for green gram and 86 % for black gram when operated at speed of 1.56 km/h. Average plant to plant distance was observed to be 6.73 cm, 6.55 cm for green and black gram during field evaluation. These observed spacing were close to desired spacing (6.28 cm) which intended in the precision metering mechanism. A unit's cost is approximately INR 2000. It facilitates sowing of pulse crop's seeds without investing extra cost on purchasing separate planter required for it. This retrofit type proposed module will make cultivator as a precision planter suitable for sowing different crops at a very low cost.

Keywords: Electronics, Mechatronics, Microcontroller, Precision planter, Rotary encoder Retrofit, Seed metering module

1 Introduction

Sowing is one of the critical operations because of non-uniform distribution of seeds results in reduction in crop yield and production.[1] Uniform seed distribution and performance of sowing machines depends on type of seed metering mechanism, speed, depth, soil covering and compaction attachments.[2] Due to agronomical requirements of different crops, there is always some scope of improvements in seed metering system used to meters seeds. The conventional seed metering system consists of a ground wheel, chain-sprocket power transmission, and seed metering unit. Major factors which results in improper placement of seed are slippage between wheel and ground, skidding of ground wheel and vibration of mechanical transmission.[3,4] Researchers reported that higher forward speed also adversely affects uniform planting. To overcome these drawbacks in planter, the seed metering system should be independent of ground wheel and equipped with alternate power transmission methods for higher precision[5,6]. An electronic metering system for a planter is an excellent option to ensure higher accuracy and performance. Several studies reported that mechatronic driving system in planter have more advantage than convention system in term of lower frictional losses, wheel slippage, and missing index.[7,8] Also, application of mechatronics driving system in planter is suitable for high-speed planting.[8] The output of a crop with precision seeding is 10–30% more than the conventional drill.[9] So, a precision planter with attached electronics seed module can save seeds and control the sowing depth, sowing distance and plant densities.

Precision planting is a prerequisite for mechanized cultivation and an important factor in efficient input use. In the precision planter, row-to-row and seed to seed distance is maintained which provides sufficient space for proper growth of individual plant. In addition, it facilitates intercultural operations with ease which results in higher yield and productivity. Due to high cost of precision planters and seed,

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farmers are unable to perform precision planting or seeding of small seed in their fields. Also, agriculture requires new monitoring and control equipment and embedded systems for agricultural implements. Embedded microprocessors in the in strument provides the capabilities of self-calibration, self-diagnosis and local analog-to-digital and digital-to-analog conversion. These intelligent systems are having sensors, actuators, control elements and supervision and control units, all of them intercommunicating in real time. Application of mechatronics in agriculture is a step toward technological advancement. The microcontroller/ microprocessor for control of electronic circuitry is available at low cost with versatile usage. Microcontrollers are used as per the need for actuation of motors/drivers and sensing of signals. Sensors facilitate seed placement, depth and distance control.[10,11] Using electronics in a metering mechanism may be one option to achieve accurate seed spacing with high efficiency.[8,12] Different types of seed metering mechanisms such as finger pick up, vacuum, air pressure, air blowing and central drum seed meter are used in various studies.[4,9,13-18] Seed metering mechanism is actuated either by the ground wheel through mechanical transmission or electronic actuation. However, the electronic actuation system for seed metering is more accurate and precise.[8,12, 19, 20] An electronically controlled metering mechanism for okra seeds based on a closed-loop Proportional Integrated Derivative (PID) algorithm was developed and performance found better than mechanical metering mechanism.[21] The developed mechatronics system performed better at higher speed (13 km/h) compared to ground wheel actuated planters. So, there is a need to develop low cost electronic planting units which should meet the need of farmers with precision as well as affordability.

In India, the legume seeds are sown either by broadcasting or using conventional cereal crop seed-drill. Traditional seed drill results in a higher seed rate, requiring thinning operation with additional labour.[22]Legumes are the most important source of protein and fibre. Legume crops are grown in winter and harvested in the spring and the subsequent season in Asian countries.[23] There is hardly any attempt for legume seeding using electronic seed metering as a retrofit to a cultivator. Most of mechatronics systems are at research stage. Also, very few studies have been carried out to control the speed of the metering plate by coupling a

micro-controlled stepper motor. Therefore, a study on retrofit type microcontroller based low-cost seed metering module consisting of an electrical motor, seed metering plate, ground speed sensor (encoder) was undertaken for precision metering of green (*Vigna radiata*) and black gram (*Vigna mungo)* legume seeds.

2 Materials and Methods

Components of the planter were designed based on physical properties of green and black gram seeds. The methodology for determination of physical properties are described below, along with selected values for metering system design.

2.1 Physical properties of seeds

Physical properties namely size, shape, bulk density, angle of repose and thousand-grain weight were determined using standard procedure adopted by researchers.[24-27, 28]

2.1.1 Size and shape

One hundred seeds were selected randomly from commonly sown varieties of black gram (variety PU 31) and green gram (variety PUSA VISHAL). Three principal dimensions; Length (L), breadth (W) and thickness (T) were determined using a digital verniercalliper. The measurements were taken five times. The geometric mean dimension (GMD) and sphericity (φ) were determined using a relationship given in literature.[24,27] Shape and size were used to determine design values for groove length, depth, and seed to be filled.

2.1.2 Bulk density

Bulk density was determined using a wooden cube of known volume (10 cm $\times$ 10 cm $\times$ 10 cm) and weighing the quantity required to fill it.

2.1.3 True density

True density of pulse seeds was determined by the hexane displacement method.[24] Ten samples were evaluated for the true density. Bulk density and true density values were used for hopper design.

2.1.4 Angle of repose

The angle of repose (θ) was determined using relationship developed by previous studies.[26-29] The experiments were carried out ten times to determine mean angle of repose of seeds.

2.1.5 Coefficient of static friction

Coefficient of static friction (μ) was determined for four structural materials, namely plywood, aluminium, iron and galvanized steel sheet commonly used for processing machines.[30,31] The coefficient of

static friction was expressed in terms of tan (α). The procedure was repeated ten times, and mean value was calculated. The coefficient of friction and angle of repose are required for designing the angle of the hopper.

2.1.6 Thousandgrain weight

Thousand seed grain weight is one of the deciding factors for desired seed rate. Ten samples were randomly selected for average weight of one thousand seed of each selected variety and weighed using an electronic balance with the least count of 0.01g. Thousand-grain weight was used to determine number of grains required per square meter area for the desired seed rate.

2.2 Design values for seed metering module

The metering system consisted of a ground wheel, incremental optical rotary encoder (B01N1ZX86W), microcontroller (ATmega328P), motor driver (BH-MSD- 3.5A Micro), stepper motor (17HS4417B15-X3), seed metering box with hopper and seed metering plate. Rotary encoder sensed rotational speed of the ground wheel. Also, generates pulses and transmits them to the microcontroller. Microcontroller controls speed of stepper motor attached to the seed metering plate shaft. Ground wheel diameter was 30 mm, and rotary encoder was mounted on hub of the ground wheel. An incremental rotary encoder (optical) with 400 pulse/ revolution was selected for the study. Forward speed of the planter was calculated from equation (1).

$$v = \frac{f_r}{400} \times \pi D \qquad \cdots (1)$$

Where,

v = forward speed of planter, m/s

f_r = number of pulse/second generated by the encoder

D = diameter of the ground wheel, m

The edge-drop cell type of metering mechanism was considered for this study. Based on size and shape of seeds, design values of cell diameter, number of seeds per cell and the number of cells per plate were determined based on required seed rate and seed spacing. The number of cells in metering plate were calculated as per given below equation (2).

$$C = \frac{\pi \times D \times S_n \times R_s}{T_r} \qquad \cdots (2)$$

Where,

C = number of cells on seed plate

D = diameter of the ground wheel, m

S_n = number of seeds/m^2 [53seeds/ m^{2}withseed rate (12 kg/ha) and weight per thousand seed (23.69 g)]

R_s = row spacing, m (0.3m)

T_r= transmission ratio (1)

The transmission ratio can be regulated with help of a microcontroller to obtain desired seed spacing. Diameter of seed metering plate was 100 mm, with a thickness of 8 mm. The groove size was kept between 5 to 6 mm, which was 1 to 1.2 times of maximum seed dimension. Theoretical seed to seed spacing was calculated as per equation (3).

$$S = \frac{\pi D}{T_r N} \qquad \cdots (3)$$

Where,

S= Theoretical Seed to seed spacing, cm

C= Number of cells on seed plate

D = diameter of the ground wheel, cm

T_r= transmission ratio (1)

Number of cells (N) on the plate was computed as 15. The seed metering plate was designed in CREO 4.0 software and converted into STL (Standard Triangle Language) format file for 3D printing. Seed metering plate was 3D printed with PLA (Poly Lactic Acid) plastic material filament as mention in Fig. 1 (a). Seed metering module consisted of a hopper,
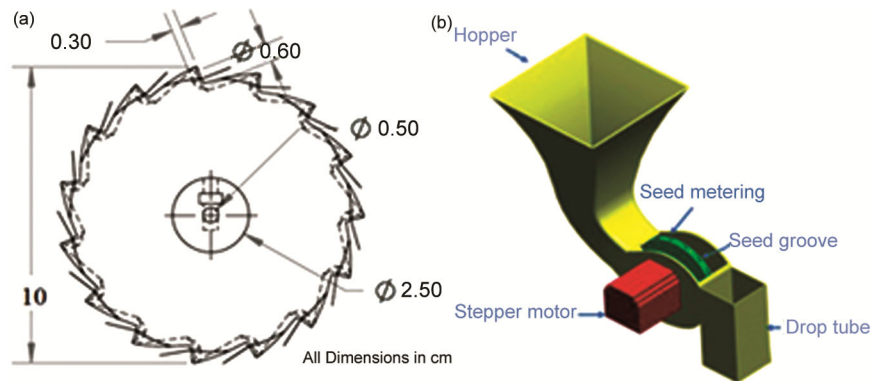

Fig. 1 — Design of seed metering system: (a) Seed metering plate, and (b) Electronic metering module.

metering box, metering plate with motor and seed delivery pipe. Seed hopper, metering box and seed delivery pipe were fabricated with a mild steel sheet (2 mm thickness). Hopper of 2kg seed capacity was mounted on the seed metering box. The seed metering box was fabricated to accommodate seed metering plate to deliver required seed quantity as shown in Fig. 1 (b). The stepper motor of 1.7 A current (Nema 17) shaft was directly connected to metering plate, which was mounted on seed metering box. The micro-stepping motor driver-controlled speed and rotational direction of the stepper motor.

2.3 Electronic seed metering control system

The ground wheel's rotational speed was sensed through optical rotary encoder and generated an alog signal transferred to external interrupt pin of the microcontroller (Fig. 2). Microcontroller (ATmega328P, 8-bit) process and transmits these signals to actuator (Stepper motor). Encoder generates signal in terms of pulses which received by microcontroller and transmit calibrated signals of micro-steps of Pulse Width Modulation (PWM) to micro step driver. Finally, micro step driver transmitted desired signal for required speed of metering plate to stepper motor. The number of cells

on seed plate and desired spacing was selected based on seed size and crop geometry (seed spacing). Microcontroller' output in form of pulses corresponds to these inputs. The pulses' frequency sent to motor driver module could be calculated from equation (4).

$$f_s = \frac{\left(\frac{V}{S}\right)}{C} \times \frac{360}{\gamma} \qquad \qquad \dots (4)$$

Where,

f_s= Frequency of pulses to motor driver module, pulse/s

γ= step angle of the stepper motor, degree

C= number of cells on the seed plate,

V= forward speed of planter, m/s

S= seed spacing, m

2.4 Circuitry of the electronic system

A 12V DC power supply was provided to Arduino Uno through step down (5V DC) voltage regulator IC 7805 fixed on the board (Fig. 3). Two signal input wires of the rotary encoder were connected to external interrupt pins (pin 2 and 3) of the microcontroller. Successive output pins from the microcontroller with pin number 4 and 5 were connected to driver module with the power supply, giving pulse signals to the stepper motor for speed and directional control. An
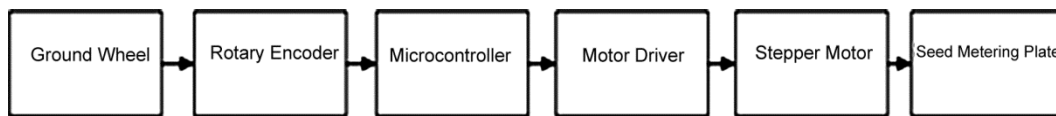

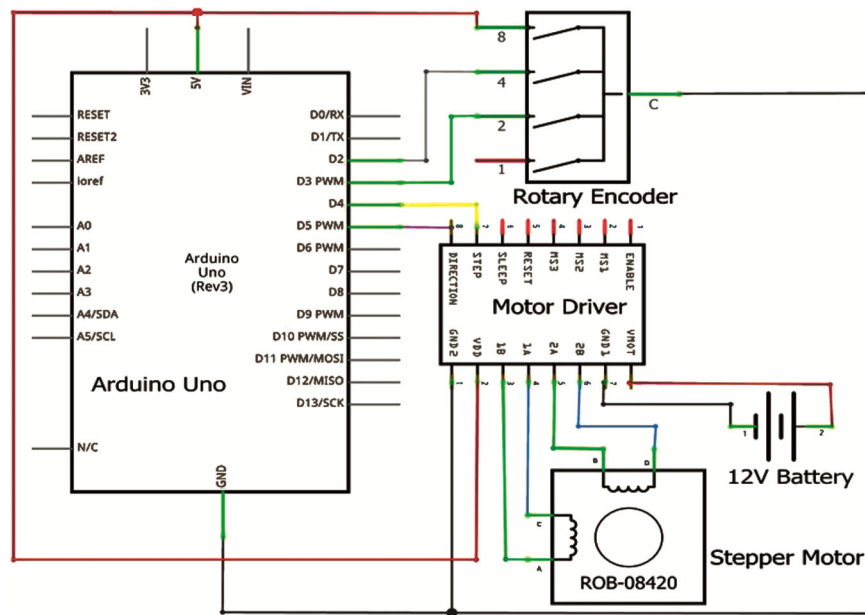Fig. 2 — Signal transmission system of seed metering mechanism.

Fig. 3 — Circuit of electronics components.

incremental rotary encoder measured value of forward speed. With rotation of the ground wheel, encoder gave a corresponding output pulse from which controller could calculate forward speed by measuring the number of pulses received. All the components were embedded in circuit, which controls speed (rpm) of connected seed metering plate.

2.5 Laboratory testing

The developed metering mechanism was tested in soil bin laboratory with dimension of 25 x 2 x 0.8 m at the Division of Agricultural Engineering, Indian Council of Agricultural Research (ICAR)-Indian Agricultural Research Institute (IARI), New Delhi. The power drive was provided to implement carriage using an endless rope and winch system, driven by an electric motor. The developed seed metering unit was fitted on the implement carriage (Fig. 4). Standard sticky belt of width 120mm was laid under seed tube of seed metering unit for evaluation. Experiments were conducted atthree speeds (1.23,1.56 and 1.8kmh⁻¹), three metering plates with 5, 5.5 and 6mm cell diameter for the seeds of black and green gram. Performance parameters, namely average spacing, quality of feed index (QFI), seed rate, multiple index (MULT), miss index (MI) and precision index (PI)were determined for all the combinations. The spacing parameters were determined as per Test code[32] using a sticky belt method. The uniformity of seed distribution along the length of the row was analysed using methods described by Kachman and Smith[33]. Spacing more than 1.5 times the nominal

seed spacing is considered as "Miss Index". QFI is the percentage of seed spacings between more than half but not more than 1.5 times the nominal spacing and indicates the percentages of single seed drops. Precision index is the coefficient of variation of the spacings (length) between the nearest seeds in a row that are classified as singles after omitting the outliers consisting of missing-seedings and multiples. QFI, MI, PI and MULT were determined by using equation 5, 6, 7 and 8 respectively.

$$QFI = \frac{S'_n}{S_N} \qquad \text{… (5)}$$

$$MI = \frac{S''_n}{S_N} \qquad \text{… (6)}$$

$$PI = \frac{S}{\bar{x}} \qquad \text{… (7)}$$

$$MULT = \frac{S_n}{S_N} \qquad \text{… (8)}$$

Where,

$S = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(x_i - \bar{x})^2}$ (standard deviation of seed spacings),

$\bar{x} = \frac{1}{N}\sum_{i=1}^{N}x_i$ (Average spacing),

$x_i =$ Nth seed spacing,

$S_N =$ Total number of seed spacing,

$S'_n =$ Number of spacing between 0.5 times and 1.5 times of the theoretical spacing,

$S''_n =$ Number of spacing in the region greater than 1.5 times of theoretical spacing and

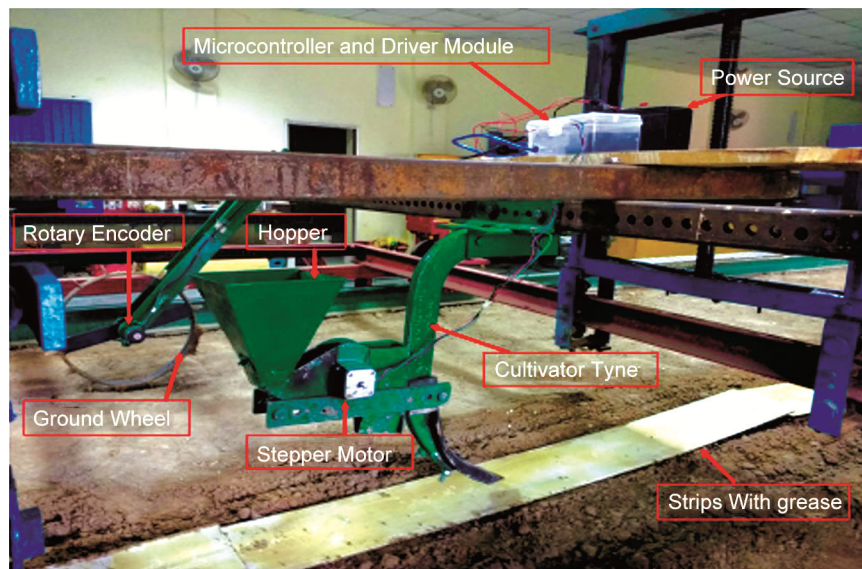$S_n =$ Number of spacing is in the region less than or equal to 0.5 times of the theoretical spacing

Fig. 4 — Evaluation of metering mechanism in the soil bin.

2.6 Statistical analysis

Completely Randomized Design (CRD) was applied for experimentation in the soil bin (Table 1). Seeds of green and black gram which have similar physical properties and cultivation season were selected for the study. Based on physical properties, cell size selected was 6.0 (D_1), 5.5(D_2) and 5.0 (D_3)mm. The forward speeds were 1.23, 1.56 and 1.80 kmh^{-1}. Experimental data recorded and analyzed using the statistical package SAS version 9.3.

2.7 Field evaluation

The developed electronic metering mechanism was retrofitted on the cultivator tyne (Fig. 5) and evaluated in experimental field at Division of Agricultural Engineering, New Delhi. A plot size of 20 × 40 m was selected for field performance evaluation in sandy loam soil. Spacing between seeds was measured in a row (3 m length) using measuring scale. The seed germination was observed after ten days, and the distance between plant to plant was also recorded.

Table 1 — Experimental Plan for laboratory evaluation in Soil Bin

Independent parameters	Levels	Dependent parameters
Seed type	2(black gram and green gram)	Seed spacing, quality of feed index, multiple index, miss index, and precision index
Cell size	3(6.0, 5.5 and 5.0mm)	
Forward speed	3(1.23, 1.56 and 1.80 kmh^{-1})	

3 Results and Discussion

3.1 Physical properties of black and green gram

Average value of physical properties of green and black gram seeds measured during analysis are presented in Table 2. Average value with standard deviation of physical properties were recorded for blackgram such as length, 4.54 ± 0.36 mm; breadth, 3.46 ± 0.27 mm; thickness,3.07 ± 0.22 mm; geometric mean diameter, 3.72 ± 0.24 mm; sphericity, 0.82 ± 0.03 (fraction); bulk density,0.84 ± 0.002g.cm^{-3}; true density, 1.35 ± 0.056g.cm^{-3}; porosity, 37.48 ± 2.62 %; thousand grain weight, 34.00 ± 1.19 g; angle of repose, 23.82 ± 0.82˚ while for green gram these parameters as length, 5.03 ± 0.52 mm; breadth, 3.76 ± 0.29 mm; thickness,3.69 ± 0.28; geometric mean

Table 2 — Physical properties of black and green gram legume seeds

Property	Black gram	Green gram
	(*PU 31*)	(*PUSA VISHAL*)
Length, mm	4.54 ± 0.36	5.03 ± 0.52
Breadth, mm	3.46 ± 0.27	3.76 ± 0.29
Thickness, mm	3.07 ± 0.22	3.69 ± 0.28
Geometric mean diameter, mm	3.72 ± 0.24	4.11 ± 0.32
Sphericity, fraction	0.82 ± 0.03	0.82 ± 0.045
Bulk density, g.cm^{-3}	0.84 ±0.002	0.86 ±0.002
True density, g.cm^{-3}	1.35 ±0.056	1.33 ±0.065
Porosity, (%)	37.48 ±2.62	35.24 ±3.24
Thousand-grain weight (g)	34.00 ± 1.19	46.18 ± 1.12
Angle of repose (˚)	23.82 ± 0.82	23.70 ± 0.73
Coefficient of friction	0.45 ±0.02	0.41 ± 0.03

Fig. 5 — Field evaluation of electronic seed metering system retrofitted on a cultivator frame.

diameter, 4.11 ± 0.32 mm; sphericity, 0.82 ± 0.045 (fraction); bulk density, 0.86 ± 0.002 g.cm^{-3}; true density, 1.33 ± 0.065g.cm^{-3}; porosity, 35.24 ± 3.24 %; thousand grain weight, 46.18 ± 1.12 g; angle of repose, 23.70 ± 0.73˚. The average dimensions of length, breadth, thickness and sphericity were used for designing the shape and size of the cells of the seed metering plate. The seed box of the seed metering mechanism was designed considering bulk density, true density, porosity, and thousand grain weight of seeds. These type properties have been also used by other researchers for design and developments of seed sowing implements like as seed-cum-ferti drill, planter etc.[19,27,34] Also, these properties will always help in designing farm machineries in future.

3.2 Laboratory evaluation of the developed seed metering module

The effect of independent variables (forward speed, cell size and seed types) on performance parameters (average spacing between the seeds, quality of feed index, multiple-index, miss-index and precision index) were observed and its description given below.

3.2.1 Effect of forward speed, cell sizeand seed type on average spacing

Average seed spacing of black gram for 6.0, 5.5 and 5.0mm cell size was in the range of 5.84–6.14 cm, 6.03–6.35 cm and 6.14–6.72 cm at a forward speed of 1.23, 1.56 and 1.8kmh^{-1}respectively. Similarly, the average seed spacing of green gram for 6.0, 5.5 and

5.0mm cell size was in the range of 5.84–6.23 cm, 6.22–6.52 cm, 6.17–6.85 cm, respectively. Best average seed spacing of 6.33 cm was observed for 5.5mm cell diameter at a speed of 1.56 kmh^{-1}. From the statistical analysis, it was found that average seed spacing was significantly influenced by cell size and forward speed at 5% level of significance (P<0.002). It was observed that mean seed spacing increased with forward speed and decreased with cell size. This is due to that at higher speed and smaller cell size metering plate might not have sufficient time for filling seeds from the seed hopper.[33,34] The effects of forward speed, cell diameter and seed type on seed spacing were determined experimentally in respect of theoretical calculated seed spacing value of 6.28 cm and graphically represented in Fig. 6 (a). It can be conclude that speed, cell size and seed type are deciding factor to get desired seed spacing in field during crop sowing.

3.2.2 Effect of forward speed, cell size and seed type on QFI

QFI of black gram was in the range of 82.22–84.78%, 84.09–86.36% and 84.62–85.3% for 6.0, 5.5 and 5.0mm cell size at a speed of 1.23, 1.56, and 1.80 kmh^{-1} respectively. Similarly, QFI for green gram was in the range of 83.33–85.49%, 85.4–90.1% and 80–85.7% for 6.0, 5.5, and 5.0mm cell size at a speed of 1.23, 1.56, and1.8 kmh^{-1} respectively. The observed QFI value was close to or more than 85%, which was within an acceptable limit.[33]According to
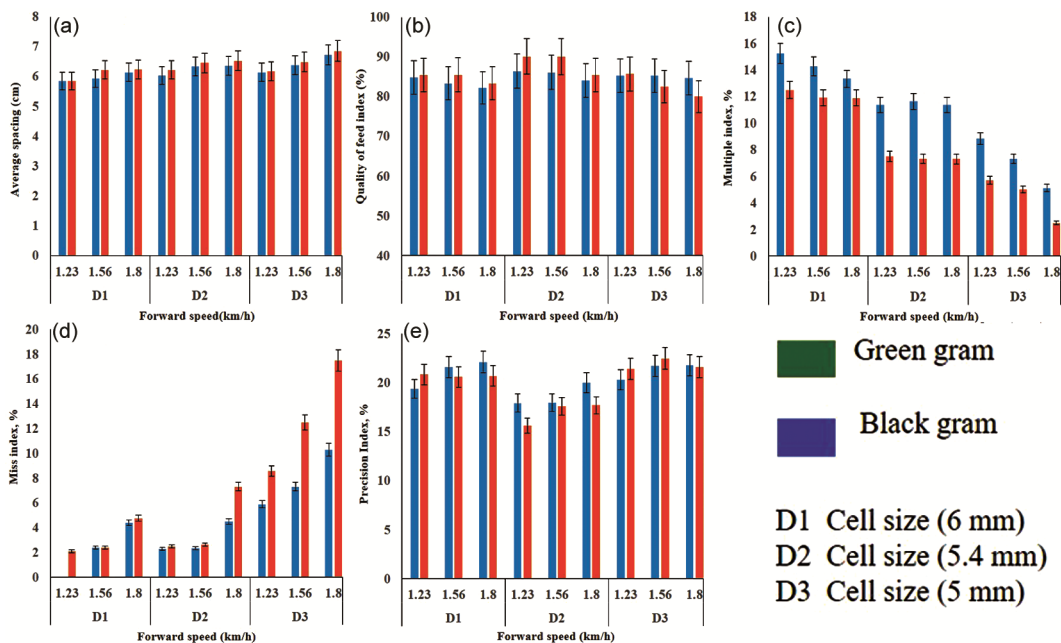

Fig. 6 — Effect of forward speed, cell size and seed type on (a) average spacing (b) QFI (c) MULT (d) MI , and (e) PI.

researcher[35], the performance of developed micro-controlled based seed metering mechanism was good as per limit values of performance criteria for precision seeding. From the statistical analysis, forward speed, cell size, seed type and their interaction significantly influenced the QFI at 5% level of significance except the interaction of cell size and speed. It was observed that the QFI increased when forward speed increased from 1.23 to 1.56 kmh⁻¹. However, QFI decreased significantly with a further increase in forward speed (Fig. 6 (b)). At a higher speed, the occurrence of more missing and multiples decreases QFI.

3.2.3 Effect of forward speed, cell size and seed type on MULT

MULT range of black gram was observed as 13.22–15.22%, 11.36–11.63% and 5.13–8.82% for 6.0, 5.5 and 5.0mm cell size at a speed of 1.23, 1.56 and 1.8 kmh⁻¹ respectively. For green gram, these values were 11.9–12.5%, 7.31–7.5% and 2.5–5.71% for 6.0, 5.5, and 5.0 mm cell size at speed of 1.23, 1.56 and 1.8 kmh⁻¹ respectively. The lowest and highest MULT of 2.5 % and 15.22 % for seeds were observed for cell size 5.0mm and 6.0mm at forward speed 1.8 and 1.23 kmh⁻¹ respectively (Fig. 6 (c). Because at a higher speed, the exposure time and space were not enough to accommodate extra seeds in the cell resulting in better singulation. MULT was highly influenced by forward speed, cell size and seed typeat 5% level of significance (P<0.001) in the statistical analysis.

3.2.4 Effect of forward speed, cell size and seed type on MI

MI values of black gram were in the range of 0–4.4 %, 2.27–4.5% and 5.88–10.26% for 6.0, 5.5 and 5.0mm cell size at a forward speed of 1.23, 1.56, and 1.8 kmh⁻¹. MI range value of green gram was observed as 2.08–4.76%, 2.5–7.31% and 8.57–17.5% for 6.0, 5.5, and 5.0 mm cell size at a speed of 1.23, 1.56 and 1.8 kmh⁻¹. The lowest value of MI 2.08% was observed for green gram with a 6.0mm cell size at a forward speed of 1.23 kmh⁻¹ (Fig. 6(d)). It was observed that MI increased with an increase in forward speed and decreased with an increase in cell diameter of metering plates. At lower speed, the cell had more exposure time for filling of seed from the hopper.[10,21] From the statistical analysis, it was observed that all independent factor and their interaction influence MI significantly at 5 % level of significance.

3.2.5 Effect of forward speed, cell diameter and seed type on PI

The highest PI was observed for green gram with 5.0 mm cell size at a forward speed of 1.56 kmh⁻¹. It represented the maximum variation of spacing compared to theoretical spacing. PI preferred should be less than 29%–30%.[33] PI increased with an increase in forward speed. The effect of forward speed, cell size and seed type on PI are presented in Fig. 6 (e).

Finally, it was observed that forward speed, cell size and seed type are the important factor to represent the performance of precision seeding and their effect should minimize with the application of mechatronics.

3.3 Field performance of the developed metering mechanism

The developed metering mechanism was retrofitted on the cultivator frame for field evaluation. From the laboratory evaluation of the metering mechanism, it was found that average seed spacing was close to desired spacing with 5.5 mm cell size at 1.56 kmh⁻¹ speed. Therefore, the retrofitted seed metering module was evaluated in the field at a forward speed of 1.6 kmh⁻¹. It was observed that plant to plant distance was 6.73 cm and 6.55 cm for the green gram and black gram, respectively. The plant to plant spacing observed was close to the calculated spacing (6.28 cm), intended in the metering mechanism design.

4 Conclusion

Microcontroller based seed metering module was developed with electronics and mechanical parts in metering system. Laboratory evaluation of developed module was conducted in soil bin for green and black gram legume seeds. Performance parameters likes as average spacing, QFI, MULT, MI and PI were measured and evaluated at three different forward speeds (1.23, 1.56 and 1.80 kmh⁻¹) and cell sizes (5.0, 5.5 and 6.0 mm) for mentioned seeds. Desired seed spacing was achieved with a cell size of 5.5 mm and a forward speed of 1.56 kmh⁻¹ for both the grams. The highest QFI for green gram was 90 % at forward speed 1.56 kmh⁻¹ with 5.5 mm cell size. MI was lowest for cell size 6.0 mm with a forward speed of 1.23 kmh⁻¹ for a black gram. MULT was a minimum of (2.5 %) for 5.0 mm cell size for green gram at 1.8 kmh⁻¹. PI was found minimum (15.64%) for 5.5 mm cell size at 1.23 kmh⁻¹. Overall, cell size 5.5 mm with forward speed 1.56 kmh⁻¹ was found best in terms of performance parameters. In the field evaluation, the same combination of cell size and forward speed gave seed spacing close to the desired value of 6.28 cm, as observed in the laboratory condition. The cost of a retrofit electronic seeding

module with a rotary encoder was INR 2000. The total cost to convert commonly available nine tines cultivator into precision seeder will be INR 18000.It can be retrofitted on the cultivator, facilitating the sowing of legume crops without investing in a separate planter. Thus, retrofit type proposed module will make cultivator as a precision planter suitable for sowing different crops at a very low cost.

Acknowledgments

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