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DEVELOPMENT AND EVALUATION OF PRECISE SEED METERING UNIT FOR SOYBEAN

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ABSTRACT

An electronically controlled precision seed metering unit for soybean was developed and evaluated in the laboratory. The seed metering mechanism of the existing seed cum fertilizer drill was changed by eliminating the ground wheel and giving revolution to the feed shaft through an electronically controlled mechanism. This mechanism was tested in the laboratory and variation in the seed rate was measured. The developed mechanism delivering the recommended seed rate with an average variation of only 1.49% as compared to 10 to 20% in conventional seed drill metering unit. The developed system was recommended to be used for the seed rate of soybean for 40-100 Kg ha^{-1}.

***Keywords*:** Metering unit, Precision seeder, Seed rate, Soybean, Uniform sowing

Introduction

Soybean (*Glycine max* L. Merril) is the world's most important seed legume, which contributes about two-thirds of the world's protein concentrate for livestock feeding (Verma *et al.*, 2015). Soybean is the numero uno oilseed crop in India. Soybean has become an important oilseed crop in India in a very short period with approximately 10-million ha area under its cultivation under five agro-climatic zones. Specific varieties are available to enhance the production and productivity of soybean in these agro-climatic zones. There has been unprecedented growth in the soybean; an area which was just 0.03 m ha in 1970 and has reached 9.30 million ha in 2010 (Agarwal *et al.*, 2013).

Mechanization is the key to enhance production with optimum resource utilization. With increased mechanization sustainable agriculture is also duly important to save the input used in crop production system i.e. Seed, fertilizer, irrigation water, chemicals, machinery, etc. (Kumar *et al.*, 2018a; Patel *et al*, 2018; and Guru *et al* 2018). Precision agriculture (PA) is an important role in achieving optimum production and productivity with ensured profitability, sustainability, and protection of the environment. The technology of precision agriculture aims to develop the capability of site-specific crop management. Variable-rate application is one of the main components of precision agriculture. Seeds are one of the most expensive inputs, therefore growers need to plant the right amount of seed to minimize input costs and increase profitability. The seed drill includes a seed metering unit which is driven from a ground wheel that is rolling on the soil surface for metering seed at a rate proportional to the forward speed of the implement (Kumar *et al.,* 2018b). For changing the seeding rate either the transmission ratio between the ground wheel and the driveshaft connected to the fluted feed wheels are changed, or the fluted feed wheels are shifted to the drive shaft transversely within the meter housing to adjust the effective metering area of the wheels (Guru *et al.,* 2015). Therefore, it has been very difficult for the operator to precisely adjust the seeding rate when moving to a new field or when changing seed varieties and it has been practically impossible to change the seeding rate on the running conditions (Minfeng *et al.,* 2018).

Precision seed devices can address many inefficiencies experienced in a mechanical seed metering device and have the potential to increase productivity and yield rates dramatically (Singh *et al.,* 2012; and Kumar *et al.,* 2025a). According to researchers seed meters driven by electrical or hydraulic motors can efficiently eliminate non-uniformity of seed caused by slippage of ground wheel and vibration of sprocket chain and therefore increases working speed and improve planting accuracy (Namdeo *et al.,* 2022). The necessity for highly accurate and high-performance agricultural machines is the main reason for the incorporation of electronic systems in this equipment, furthermore, the new planting units are more user-friendly. Electronically transmission systems can prove a very good option for precision sowing of seeds with the advantages of uniform seed rate application and easily adjustable seed rate (Singh *et al.,* 2005). To achieve these advantages an electronically controlled seed metering unit is developed in the laboratory and evaluated for its performance under simulated field conditions (Miller *et al.,* 2012; and Kumar *et al.,* 2023).

Materials and Methods

The performance of the metering device can be checked more readily and more reliably in the laboratory than in the field (Kapner *et al.,* 1978). The Indian standard IS 6316: 1993 sowing equipment seed-cum-fertilizer drill test code recommends the following performance parameter of seed drill under the lab testing viz (Kumar *et al.,* 2025a). Seed rate and uniformity – seed rate determine the seed dropping rates obtainable at different settings and the variation among furrow openers when the machine is stationary by the calibration method. Uniformity is determined whether the drill is placing the speed uniformly or not. The study was carried out at the Department of Farm Machinery & Power, College of Agricultural Engineering, Jawaharlal Nehru Krishi Vishwavidyalaya, Jabalpur, MP, India (Kumar *et al.,* 2025b; and Kumar *et al.,* 2023).

Development of laboratory setup of the precision seed drill

Microcontroller

For the development of an electronically controlled seed metering unit, Arduino Mega 2560 microcontroller board was used. This board has an AT mega2560 microcontroller that was powered by 5V. It has 54 digital input/output pins (of which 15 can be used as PWM outputs), 16 analog inputs, 4 UARTs (hardware serial ports), a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller (Namdeo *et al.,* 2020). An LCD, potentiometer, light-emitting diode (LED), voltage regulator, capacitors, and the resistor is also connected to the microcontroller

DC motor

DC motor (DCM) is the most commonly used actuator for producing continuous movement and whose speed of rotation can easily be controlled, making them ideal for use in applications where speed control, servo type control, and/or positioning is required (Kamgar *et al.,* 2015). The speed of rotation of any DC motor can be varied from a few revolutions per minute (rpm) to many thousands of revolutions per minute and it is making them for electronically controlled seed drill. For calculating the required power of DC motor, first, the maximum static torque coming on seed metering shaft was calculated. For that purpose, a load cell was mounted at the end of the MS-flat rod which was connected to the seed metering shaft. The load cell was pulled down manually and the force (kgf) readings were noted down (Cay *et al.,* 2018). The maximum static torque was calculated by multiplying the avg. force to the known distance of MS-flat from the center of the main shaft. The maximum static torque was 10.19 Nm. The maximum rotational speed of the shaft was decided corresponding to the maximum speed of operation for seed drill. The speed of operation and seed rate was assumed to be 5 km/h and 100 kg/ha, respectively (Liang *et al.,* 2015). Thus, the maximum rotational speed of dc motor was 48.9 rpm was obtained to drive seed metering shaft and with considering gear reduction 5.22: 1, shaft. The power required for the rotation of the shaft was determined (Kamgar *et al.,* 2013). For the present study, a 350watt, 24-V DC motor was chosen. The gear ratio between the metering shaft and the motor was calculated as 5.22:1 and the Rpm of the dc motor was found 48.9114 Rpm for 100 kg seed rate of soybean.

Controller

The controller includes an automatic means for starting and stopping the motor, selecting forward or reverse rotation, selecting and regulating the speed, regulating or limiting the torque, and protecting against overloads and faults. Pulse width modulation is a great method of controlling the amount of power delivered to a load without dissipating any wasted power. In the present study, a DC 9-60V Motor Controller 20A Motor Driver module was used. It has 12V/24V/36V/48V positive H4N4 Input voltage DC9-60V (Kamgar *et al.,* 2015; and Namdeo *et al.,* 2020). A brief specification of the controller was given in table 1.

Proximity sensor

Inductive proximity sensors are used for non-contact detection of metallic objects. Their operating principle is based on a coil and oscillator that creates an electromagnetic field in the close surroundings of the sensing surface. Before installation of the proximity sensor switch, two Iron spoke wheel was designed with the help of lath machine and arc welding. 8 number of iron spokes were welded on its periphery at the interval of a 45-degree angle (Cay *et al.,* 2018). After that one spoke wheel was mounted at the simulated front wheel (SFW) of the tractor for calculating the forward speed of the tractor and another wheel was mounted on the output shaft of DCM. After mounting of iron wheels, two non-contact inductive type proximity sensor switches were used. One proximity sensor was mounted at SFW of the tractor and the other at the platform of the motor respectively (Liang *et al.,* 2015). The proximity sensor was mounted in such a way that the distance between spokes of the wheel and sensor could not more than 8mm as per recommendations of the manufacturer (Cay *et al.,* 2018; and Namdeo *et al.,* 2020). The proximity sensor of SFW was used for the measurement of the forward speed of the tractor. The proximity sensor of the motor was used to calculate the desired rotational speed of DCM. After installation, both proximity sensors were calibrated at different RPMs.

Table 1: Specification of variable rate controller of dc motor

Sr. No.	Particular	Specification
1.	Input supply voltage	DC 9V to 60V
2.	Max current	20A
3.	Sustained current.	18A
4.	PWM frequency	25KHz
5.	Adjustable speed range	0%-100%
6.	Speed adjustment way.	Potentiometer
7.	Output voltage	Linear under load
8.	Speed control type	Basins
9.	Dimensions	90 x 50 x 35 (LxWxH) mm
10.	Cable Length	130 mm
11.	Output voltage	Load Linear
12.	Continuous power	1200W
13.	Type	Adjusting flow
14.	The motor running condition adjustment	Forward / Stop / Reverse
15.	Reverse polarity protection	Yes
16.	Suitable Motor	DC brush motors.
17.	Weight	155 gm.

Working of the precision seed drill

The values of no. furrow opener of the seed drill, the spacing between furrow openers was uploaded on the microcontroller. The desired seed rate according to the type of crop was set by the operator through the control knobs (rotary potentiometers) provided at the control box of the system. Velocity readings were sent to the microcontroller by the proximity sensor (Namdeo *et al.,* 2020). By this data, the microcontroller computed the rpm of DC motor is proportional to the forward speed of SFW of the tractor for set values of seed rate. Consequently, knowing the forward speed and the seed rate, the actual seed rate was calculated by the system. For optimization of forwarding speed, the Microcontroller counted the total seed in kg per revolutions of seed metering shaft. The structure block diagram of the developed system is shown in Fig. 1. Once the rate of the desired seed rate is set by the operator (Cay *et al.,* 2018). The microcontroller computed the rpm of the DC motor is proportional to the forward speed of the tractor for set values. Velocity readings were sent to the microcontroller by the proximity sensor. After this, Microcontroller sends a PWM signal to the motor controller corresponding to the calculated rpm of the DC motor and the motor controller sets the motor rpm as the desired rpm. The power is transmitted from the DC motor to the main seed metering shaft via chain drive. Finally, the main shaft rotates the seed metering mechanism (Liang *et al.,* 2015).

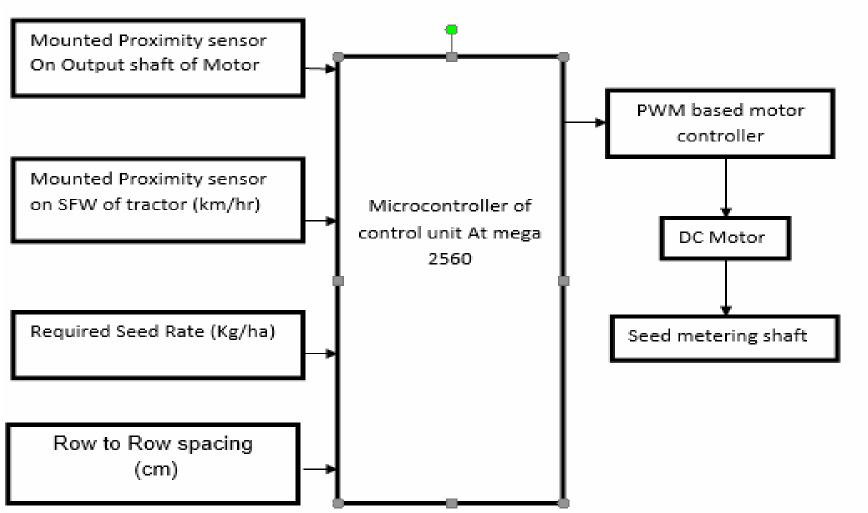

Fig. 1: The structure block diagram of the developed system

Testing of developed setup

The developed setup incorporated with 9 Tyne seed drill in the laboratory for its performance with Soybean seeds. To examine the ability of the developed electronically controlled seed metering unit, a laboratory setup was built (Liang *et al.,* 2015). The overall view of the lab setup is shown in Figure 2. The lab setup consisted of a test seed drill coupled to a DC motor via a chain drive, a DC motor controller to vary the speed of the DC motor, an Proximity sensor mounted on the SFW of the tractor, a proximity sensor to measure operating rpm of motor and an Arduino Mega 2560 microcontroller to synchronize sensors signals. A laptop was used to collect data from the microcontroller

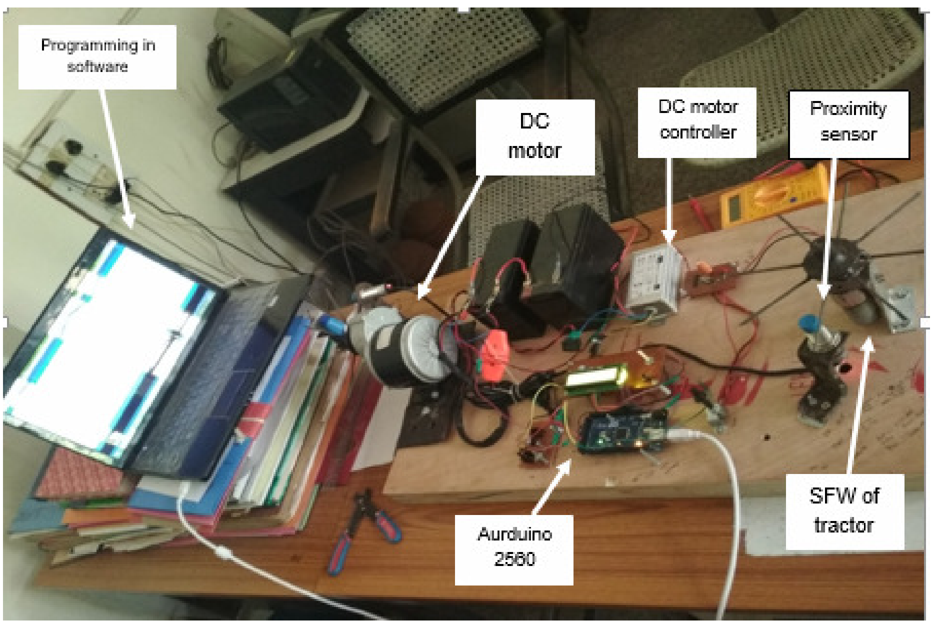

Fig. 2: View of lab setup of the precision seed drill

Test procedure

Graded seeds of soybean were used for this study. The experiment was carried out using the seed drill coupled to a DC motor via chain drive. The desired seed rate was 40, 60, 80, 100 kg ha^{-1} and spacing between furrow opener was 20 cm. Performance evaluation of the developed system was conducted under four operating speeds of 2, 3,4, and 5 km h^{-1} (Kamgar *et al.,* 2015; and Liang *et al.,* 2015). To resemble the operation of the seed drill at 2, 3, 4, and 5 km h^{-1} speed, the SFW of the tractor (electrical motor) was set to run at 40.25, 60.38, 80.21, and 100.65 rpm, correspondingly. Three replications were taken at each forward speed with each set seed rate. Observations were taken and then a comparison was done between the set seed rate and actual observed seed rate to evaluate the performance of the developed metering unit (Namdeo *et al.,* 2020; and Kamgar *et al.,* 2015).

Results and Discussion

Effect of operating speed on seed rate

It was observed that % variation in seed rate over the set seed rate varied from – 2.99% to 2.2 % at 5 km h^{-1} forward speed of operation within the seed rate range of 40 kg ha^{-1} to 100kg h^{-1} for soybean. The average variation of seed rate at 5 km h^{-1} speed was 1.25 %. There was a linear relationship between the recommended seed rate and the obtained seed rate with the R^2 value 0.99. Similarly, the test was conducted for the operation speed of 4, 3, and 2.4 km h^{-1} (Table 2). For an operating speed of 4 km h^{-1}, it is observed that % variation in seed rate over the set seed rate varied from 0.85% to 1.87 % with the seed rate range of 40 kg ha^{-1} to 100 kg ha^{-1}. The average variation of seed rate at 4 km/hr speed was 1.25 %. The same pattern of seed rate variation from –0.58 % to 3.11 % at 3 km h^{-1} forward speed of operation for the seed rate range of 40 kg ha^{-1} to 100 kg ha^{-1} for soybean. The average variation of seed rate at 3 km h^{-1} speed was 1.69 %. The data shows the linear relationship between the recommended seed rate and the obtained seed rate with the R^2 value 0.99. For the operating speed of 2.4 km h^{-1}the variation in seed, the rate was ranged between 1.03 % to 2.03 % for seed rate of 40 Kg ha^{-1}to 100 ^{Kg} ha $^{-1}$. The average variation of seed rate at 2.4 km/hr speed was 1.69 %. The observed data shows a linear relationship between set seed rate and obtained seed rate with the R^2 value 0.99.

Table 2: Recommended and actual seed rate (Kg/ha) corresponding to different forward speed (km/h)

Recommended seed rate	Speed							
	5		4		3		2.4	
	Actual seed rate	% Variation	Actual seed rate	% Variation	Actual seed rate	% Variation	Actual seed rate	% Variation
40	39.87	-0.30	40.23	1.42	40.59	1.49	40.53	1.33
60	60.92	1.54	60.72	1.20	60.87	1.46	60.98	1.63
80	81.63	2.04	80.99	1.23	81.88	2.35	80.97	1.22
100	101.72	1.72	101.01	1.01	101.48	1.48	101.78	1.780

In the present study, to solve problems associated with a conventional seed drill, a microcontroller-based system for seed drill was developed in which the mechanical transmission system was replaced by an electronically controlled seed metering unit. The electronic control system consisted of a 350 W, 24-V DC motor, a 9-60 V., a 20A motor controller having 25 kHz PWM Frequency, Arduino mega 2560 microcontroller, and associated circuitry. To control the operations of the system, an embedded circuit was developed. The embedded circuit of the system consisted of two 16x2 LCDs, two Rotary potentiometers, 7805 voltage regulator IC. The values of seed rate according to the type of crop were set by the operator through the control knobs (rotary potentiometers) provided at the control box of the system. Velocity readings were sent to the microcontroller by the proximity sensor. By these data, the microcontroller computed the rpm of DC motor is proportional to the forward speed of tractor for set values of no. of holes and desired seed spacing. Power to DC motor was supplied by the two batteries of 12V in series (12V&80Ah). Chain drive was used to transmit the power from DC motor to seed metering shaft. A proximity sensor with an iron spokes wheel was mounted on the motor output shaft to sense the rotational speed of the DC motor and to provide the feedback signal to the motor controller for compensating the motor rpm during load changes. Lab testing results indicated a major reduction in variation of seed rate which was an average of 1.49% as compared to 10 to 20% in conventional seed drill metering unit and 2.16±0.71% reported by (Singh *et al.,* 2012).

Conclusions

The developed metering system shows a strong linear relationship between the actual and the set seed rate by software measured number of seeds at all forward speeds (2.4, 3, 4, and 5 km h^{-1}). The developed system improved the performance of the seed drill. The developed system is capable to accommodate seed rate up to 100 kg ha^{-1} seed rate for soybean. The input cost of sowing will be reduced by a developed unit and a manufacturing cost will be decreased by the replacement of conventional seed metering unit with developed electronically control metering. The saving in seeds and uniform plant population results in better utilization of other inputs, i.e. fertilizer, chemicals, irrigation water, etc which results in saving of input cost and results in better crop yield.

Acknowledgement and Conflict of interest

The contribution of all author for this research article is equal. All the research work has done under the supervision of Atul Kumar Shrivastava, Manish Patel, Prabhat Kumar Guru, and Rakesh Paliwal in the College of Agricultural Engineering, JNKVV, Jabalpur. Author Rohit Namdeo designed and developed the precise seed metering unit. Author Rohit Namdeo, Avinash Kumar, Y. Nandini, and Indraveer Singh completed all experiments in the laboratory and prepare this manuscript. The manuscript corrected by Atul Kumar Shrivastava, Prabhat Kumar Guru, Manish Patel, and Rakesh Paliwal. There is no any area of conflict by any funding agency involved in this research work.

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