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Embedded System for Precision Cotton Planting

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It is imperative to use a single seed planter to ensure uniform distribution of seeds. Through transmission members such as chains, gears, shafts and belts, conventional planters' seed metering mechanism receives motion from ground wheels. Mechanical planters are often unable to maintain spacing due to transmission loss or a slippage. In order to make precision planting, an embedded system comprised of a microcontroller, stepper motor and rotary encoder developed and fitted to a cotton planter. The response time of the system was 200 milisecond. The developed setup fitted to cotton planter has been calibrated in the laboratory on sticky belt to assess the missing index (Mi) (%), multiple index (Mui) (%), quality of feed index (Qfi) (%), seed spacing (Ss) (mm) and seed rate (kg/ha). Results indicate that precision seeding meets the "good" performance criteria for Mi (3.21%), Mui (4.53%), and Qfi (92.26%). Furthermore, the spacing of the seeds and seed rate were found to be 607.3 mm and 2.56 kg/ha, which is in line with recommendations. Performance of Cotton planter fitted with embedded system was evaluated in the field and results were compared with existing cotton planter. The cotton planter equipped with an embedded system achieves plant spacing values of (607.3 ± 1.59), which are closer to the desired spacing. The embedded system fitted cotton planter saved 13 and 11.5% of seed rate and operational costs in contrast to existing cotton planter. The cost of embedded system was Rs. 40,000. By removing only the power transmission system, the developed system would be suitable for tractor and power tiller-operated seed drills and planters.

Keywords: Cotton planter, Microcontroller, Precision, Seed sowing, Seed spacing

Introduction

Modern agriculture is characterized by the increased use of tractors for various field operations *viz*., seedbed preparation, sowing, plant protection, weeding and intercultural, harvesting and threshing. Despite the fact that tractor use in India is increasing at a steady rate, there is lacuna in development of precise machinery for the operations which demand operational accuracy so as to reduce inputs costs.[1] Cotton is one of the most important commercial and fiber crops in India. Around 25% of the world's cotton is grown in the country with an acreage of 12.5 lakh hectares, which places the country first in cotton acreage. Despite this, the average yield of 510 kg/ha is still lower than the global average yield of 789 kg/ha due to conventional sowing practices, poor pest and disease control, rain-fed agriculture and climate change.[2,3] One of the most crucial aspects of raising crops is the proper placement of seeds in the soil for optimal growth. Conventional sowing practices with improper seed placement in the soil can significantly reduce yields.[4]

Cotton is sown using seed drill or planter powered by animal or human, power tiller and tractor. With decrease of animal population and non-availability of human labour, power tiller and tractor operated planters gaining popularity. Precision planters are sowing machines that have single seed metering devices.[5] Most planters in use are mechanical types that operate by attaching a ground wheel, with power transmission occurring from the ground wheel, affects the efficiency of the seed metering mechanism as efficiency reduces when there are transmission losses due to slippage of the ground wheel and gear or chain losses and also subjected to wear and tear due to continuous friction between moving parts, requiring frequent maintenance as a results increase in the operational cost.[6,7] Several studies reported that mechatronic-based precision planters provide good seeding uniformity among all seeding technologies with Qfi, Mi, Mui, and precision index.[8,9] Rajaiah *et al*.[10] compared mechanical and electronic planters, finding a 12.04% savings in seed rate, a spacing

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variation of less than 4.0%, and a 16.3% increase in seed placement index when using the electronic metering method over the mechanical method.

Bansal and Mukesh,[11] and Sharma *et al*.,[12] developed and evaluated of tractor drawn Bt cotton planter with inclined cell plate type metering roller and shoe type furrow opener. The seed rate was ranged between 1.5 and 2.5 kg/ha with row to row spacing of 1.0 m and plant to plant spacing of 650-700 mm. The researchers found that the quality of feeding index was 75.57%, which falls into insufficient classification in the performance criteria for precision seeding.[13] Furthermore, plant spacing and planting density play a very important role in maximizing crop development and yield.[14] It is impossible to maintain appropriate plant spacing in the conventional planter due to many constraints. Hence, the development of precision seed planter which maintains plant to plant spacing with accurate seed rate is very crucial.

Singh *et al*.[15] have developed a controller-based seed cum fertilizer drill for soybeans, wherein the spoke wheel was substituted with a 24 V DC motor operated via pulse width modulation (PWM) to operate the seed metering mechanism. The results indicated that less seed rate variation (2.16 ± 0.71%) in developed seed drill compared to conventional seed cum ferti drill (10–20%). Leela and Saravanakumar[16] developed an optical driving wheel sensor (encoder) for measuring the speed of a motorized maize planter. Synchronization of the stepper motor driving the metering roll was based on travel speed information. The Qfi was measured at 94.75%. In the review study, there was only one study on a mechatronic-based 4-row inclined plate seed metering planter for cotton seeds[17] with a solenoid shutter valve actuated by a proximity sensor on the ground wheel for precision seed metering. The average distance between seeds along the row and the standard deviation were 433.3 mm and 20.17 mm, respectively. However, farmers must change metering mechanism in order to attach developed setups, which is an additional cost to them. According to the aforementioned studies, an embedded system with a sensor is all that is required to carry out precise seeding rather than whole new development. Further, as per our review study, no research has been conducted to develop microcontroller based planter for cotton that maintains both plant to plant and row to row spacing. In order to make cotton planters more precise, the current study was conducted to develop an embedded system suitable for them. Further, results were compared with existing cotton planter.

Materials and Methods

Description of Cotton Planter

The commercially available tractor drawn cotton planter having inclined plate type seed metering mechanism was selected to modify precision planter with embedded system. The planter consists of main frame, seed box, power transmission system, ground wheel and furrow opener. The main frame consist of two main parallel MS hollow rectangular bar section of 2500 × 65 × 65 mm with thickness of 5 mm, two MS angular bar of size 500 × 50 mm attached connecting two main parallel MS hollow rectangular bar at a distance of 2120 mm from both the ends. Three-point linkage of category-II attached to the main frame at the front side to hitch the planter to the tractor. Four seeds box having a shape of rectangular at the bottom side and semi-circular at the top side of which the rectangular section size of 200 × 120 mm and the semi-circular size of radius 102 ± 0.50 mm and height of the seeds box 204 mm. The power transmitted to metering plate from ground wheel through chain sprocket and gear drive. The diameter of the ground wheel is 360 mm and thickness is 80 mm. The size of lugs consists of trapezoidal shape with longer length 70 mm, smaller length 50 mm with lateral side length of 46 mm. Planter consists of Shovel type of furrow opener and seed tube made up of PVC pipe and the diameter of the pipe was 40 mm with 1 mm of thickness. The planter has adjustment to change row to row spacing from 600 to 900 mm. It consists of drag type furrow covering device to ensure soil and seed covering. For the present study, recommended row to row distance of 900 mm was set with three seed metering unit.

Development of Embedded System for Planter

The embedded system comprised of micro-controller (Arduino Nano), stepper motor, motor driver module, rotary encoder, LCD with I2C module, step down converter and battery (Table 1). A rotary encoder was attached to the ground wheel in place of the power transmission unit from ground wheel to metering shaft. Using the rotary encoder, the rpm of the ground wheel is measured in pulses per revolution, which are transmitted to a microcontroller that then actuates the stepper motor connected to the main shaft of the seed metering mechanism. The

Table 1 — Components used to develop embedded system

Sl. No	Component name	Specification
1	Microcontroller	ATmega328, Operating voltage: 5 V, Analog input pins: 8,
2	Micro stepping driver	BH-SMART-4.5A, DC Power Input: 20 – 72 V, Micro stepping: 200, 400, 800, 1600 and 3200
3	stepper motor	BH57 SH 56-2804 AK, Motor Type: Bipolar, Step per revolution: 200, Holding torque for motor: 1.26 Nm
4	Rotary encoder	Encoder Type: Optical, Pulse Per Rev: 2000PPR, Operating Voltage: 5–24 Vdc
5	LCD display	20 × 4 LCD black on yellow/green
6	Power source	Battery, 24 V 65Ah

Arduino Nano served as the microcontroller unit, powered by either a 6–20 V unregulated external power supply (connected to pin 30) or a 5 V regulated external power supply. While the microcontroller and I2C module operated on a low voltage of 5 V, the main power supply was 24 V provided from separate battery. To bridge this gap and meet the 5 V requirement, a step-down converter, LM-2596, was employed. For motor control, a current amplifier, acting as an interface between the motors and control circuits or operating system, was utilized. Specifically, the BH-SMART-4.5A series of micro-stepping drives served this purpose. This driver featured two connectors: P1 for control signal connections and P2 for power and motor connections. A 20 × 4 LCD display was employed to showcase the RPM (rotations per minute) of the ground wheel on the panel box. Given the need for high torque to rotate the main shaft of the planter at low speeds, a stepper motor (BH57 SH 56-2804 AK) was selected. The circuit diagram of the embedded system is shown in Fig. 1. Planter rpm, pulses, and seed rate are displayed on the LCD. Power for the entire system was provided by tractor battery. The cotton planter fitted with embedded system is shown in Fig. 2.

Laboratory Calibration of Cotton Planter Fitted with Embedded System

Prior to conducting laboratory calibration, engineering properties of seeds — including sphericity, moisture content, seed size, thousand seeds weight, bulk density, coefficient of friction, and angle of repose — were measured or determined as described by Mohsenin.[18] These parameters are necessary for choosing an appropriate metering mechanism and settings of the planter. The same sticky belt reported by Abhyankar *et al.*,[19] was used to calibrate cotton planter with inclined plate metering mechanism having 10 mm size cells (Fig. 3). Through a variable drive motor, the forward speed of the belt was maintained at 3 km/h. To avoid seeds bouncing, the sticky belt was smeared with grease. After each replication, the grease was removed and reapplied for the subsequent replication, while the hopper was filled with seeds. Using standard methods prescribed by ISO 7256/1–1984.[20] The performance of the embedded system fitted cotton planter metering mechanism was evaluated for the missing index (Mi) (%), multiple index (Mui) (%), quality of feed index (Qfi) (%), seed spacing (Ss) (mm) and Sr (kg/ha). Moreover, the inter-row variation of seeds across seed tubes was measured in accordance with IS: 6813[21] standard.

$$M_i = \frac{n1}{N} \times 100 \quad \dots (1)$$

$$\text{Mui} = \frac{n_2}{N} \quad \dots (2)$$

$$\text{Qfi} = 100 - (\text{Mi} + \text{Mui}) \quad \dots (3)$$

$$\text{Ss} = \sum_{i=1}^{n} \frac{x_i}{D} \quad \dots (4)$$

where, n_1= Number of spacing > 1.5 times the theoretical spacing in the given observations; N = Total number of observations; n_2= Number of spacing that are less than or equal to half of the theoretical spacing; D = Total number of spacing measured; x_i = Distance between seed i and the next seed

Field Evaluation of Cotton Planter Fitted with Embedded System

Tractor operated three row cotton planter (Fig. 4) fitted with embedded system's performance was evaluated the research field of University of Agricultural Sciences (UAS), Raichur, Karnataka, India and compared with the existing cotton planter. Before conducting the field experiment, soil parameters *i.e.*, soil moisture content and bulk density

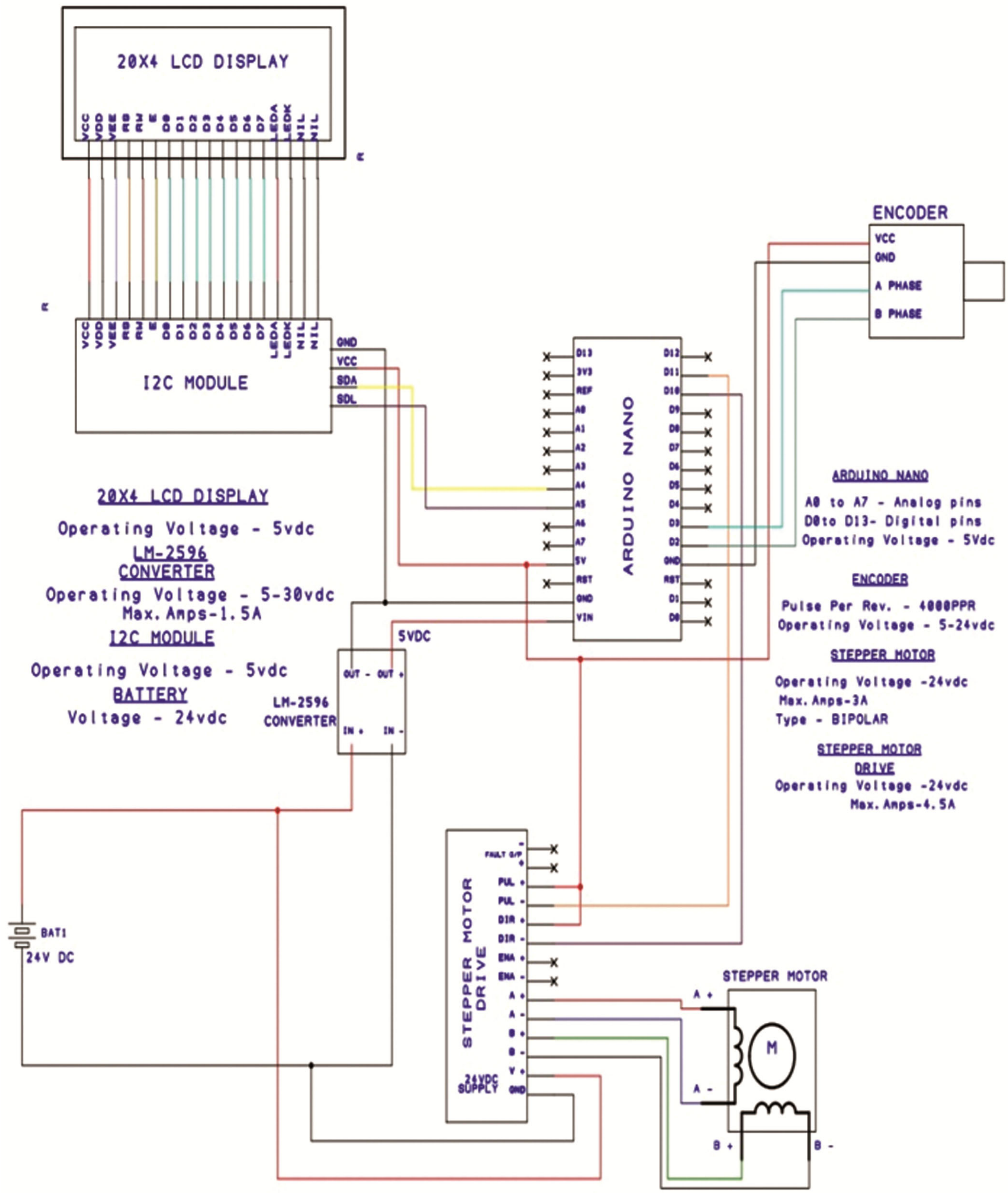

Fig. 1 — The circuit diagram of the embedded system

were studied. The performance indicators of both planter like seed spacing, depth of planting, seed rate and actual field capacity were measured in accordance with IS 6813. Further, the cost of was calculated by the method recommended by BIS test code IS 9164.[22]

Fig. 2 — The cotton planter fitted with embedded system

Fig. 3 — Laboratory calibration of cotton planter fitted with embedded system

Fig. 4 — Field evaluation of cotton planter fitted with embedded system

Results and Discussion

Before conducting the laboratory experiment, engineering properties of seeds are measured and results are presented in Table 2. The laboratory calibration of cotton planter with embedded system was tested on sticky belt and results are presented in Table 3. From the table, it is evident that the Mi (3.21%), Mui (4.53 %), and Qfi (92.26 %) indicate that precision seeding meets the "good" performance criteria reported by Cay *et al.*[13] Observed seed spacing (599.0 mm) and seed rate (2.50 kg/ha) of the planter was within the recommended range.[23] The inter-row variation of seeds (3%) dropped through different tubes was well within the range of 0-7% recommended by IS standard.

Field Evaluation of Cotton Planter Fitted with Embedded System

Tractor operated three row cotton planter fitted with embedded system's performance was evaluated and its results are compared with existing cotton planter (Table 4). Prior to conducting the field experiment, soil properties were measured/ determined. The soil type was black cotton soil with an average soil moisture content of 15.68% (d.b). The bulk density of the soil was 1445 kg/ m^3 and the cone index of the soil was 81 kPa.

Growth and yield characteristics of a plant depend on its spacing, which varies from variety to variety. Because most varieties grown in this area are bushy, they require space to grow. The maximum yield has been reported when this variety is sown at 600 mm apart. It has also been shown that the yield of cotton is affected by the plant population.[7] If the spacing is more than recommended, weeds will affect plant growth. Hence, it is necessary to maintain the recommended cotton spacing. Compared to the

Table 2 — Engineering Properties of cotton seeds used in the study

Sl. No.	Properties	Max	Min	Average (mean ± SD)
1	Variety		SRCH BG-II	
2	Size			
	Length, mm	9.87	7.65	8.55 ± 0.56
	Width, mm	6.84	3.48	5.33 ± 0.37
	Thickness, mm	6.3	4.1	4.80 ± 0.33
	Equivalent diameter (D_e), mm	7.6	5.2	6.04
3	Sphericity	0.92	0.52	0.70
4	Moisture content, % (w.b.)	10.35	6.89	8.15
5	Bulk density, kg/m^3	610	562	588
6	True density, kg/m^3	1300	920	1005
7	Hundred seed weights, g	15.62	9.57	10.63
8	Angle of repose, deg	37.2	35.8	36.9°
9	Coefficient of friction	0.72	0.34	0.55

Table 3 — Results of laboratory calibration of planter

Sl. No	Performance indices	Values observed	Limit values for good classification (Cay *et al.* [6])
1	Mi (%)	3.21	≥ 0.7 to < 4.8
2	Mui (%)	4.53	≥ 0.7 to < 4.8
3	Qf i (%)	92.26	> 90.4 to ≤ 98.6
4	Ss (mm)	599.0	—
5	Sr (kg/ha)	2.50	—
6	Inter row variation of seed (%)	3	—

Table 4 — Results of comparative tests of cotton planters

Sl. No	Performance indices	Cotton planter fitted with embedded system	Cotton planter
1	Depth of sowing	5.20^{ns}	5.32 ^{ns}
2	Variation in seed placement depth, %	10.00^{ns}	10.23^{ns}
3	Seed rate (kg/ha)	2.56	2.89
4	Field capacity (ha/h)	0.55^{ns}	0.48^{ns}
5	Operational cost (Rs./h)	Rs 1443.59/ha	Rs 1610/ha

(Tukey's range test, NS: non-significant)

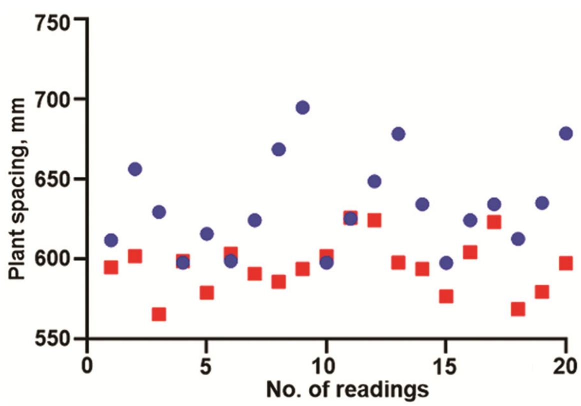

Fig. 5 — Variation of plant spacing with CPFE (Cotton planter fitted with embedded system) and Existing planter

spacing of the cotton planter with embedded system, existing cotton planter system were farther and non-uniform with spacing of 622.0 ± 4.3 (Fig. 5). This is an indicator that cotton planter with embedded system provides values (607.3 ± 1.59) closer to the desired plant spacing. Similar observation was reported by Sahu[12] for inclined type of mechatronic cotton planter.

The capacity of the existing cotton planter was less than that of the cotton planter fitted with embedded system. During the evaluation, it was found that the ground wheel and power transmission system of the existing cotton planter required regular inspection. Thus, field capacity decreased as the inspection time increased during turning. The variation in seed placement depth of both planters was less than the recommended range. According to the Table 3, the seed rate of the cotton planter without embedded system was significantly ($P<0.05$) higher. Similar observation was reported by Rajaiah *et al.*[10] An effective seed metering mechanism and proper seed signulation may be responsible for the desired seed rate of the cotton planter with embedded system. When compared to the existing cotton planter, the embedded system saved 13 and 11.5% of seed rate and operational costs. The developed embedded system has a response time of 200 milisecond.

Conclusions

In order to plant cotton with precision, an embedded system has been developed for cotton planters. The laboratory calibration of a cotton planter with embedded system was conducted on sticky belt, and the results indicate that precision seeding meets the "good" performance criteria for Mi (3.21%), Mui (4.53%), and Qfi (92.26%). Furthermore, the spacing of the seeds and seed rate were found to be 607.3 mm and 2.56 kg/ha, which is in line with recommendations. Following that, tractors fitted with embedded systems were tested in the field and results were compared with existing cotton planters. The cotton planter equipped with an embedded system offers seed spacing values that closely align with the desired plant spacing. Compared to existing planter, the embedded system fitted cotton planter saved 13 and 11.5% of seed rate and operational costs. The response time of the system was 200 milisecond. By removing only the power transmission system, the developed system would be suitable for tractor and power tiller-operated seed drills and planters.

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Conflict of Interest

The authors have no conflict of interest to declare.

Reference

1 Vinayaka, *Development and Performance Evaluation of Tractor Operated Seed Dibbler for Selected Field Crop,* Ph D Thesis, Univ Agric Sci, Raichur, Karanataka, India, 2020.

2 Gholap B & Mathur R, Field evaluation of tractor operated boom sprayer of cotton crop, *Int J Agric Eng*, **6(2)** (2013) 372–374.

3 Nagesh K T, Anantachar M, Veerangouda M, Prakash K V, Nadagouda S, Koppalkar B G, Rao S A, Murali M & Raghavendra V, Development and evaluation of a tractor-operated automatic gun sprayer for cotton crops, *Afr Entomol*, **30** (2022) 1–5.

4 Bai S, Yuan Y, Niu K, Shi Z, Zhou L, Zhao B & Ma Y, Design and experiment of a sowing quality monitoring system of cotton precision hill-drop planters, *Agriculture*, **12(8)** (2022) 1117.

5 Singh R C, Singh G & Saraswat D C, Optimization of design and operational parameters of a pneumatic seed metering device for planting cotton seeds, *Biosystem Eng*, **92(4)** (**2005)** 429–438.

6 Michael F, Yubin L & Changhe C, OPTO-Electronic sensor system for rapid Evaluation of planter seed spacing uniformity. *Biological System Engineering: Papers and Published,* **41(1) (**1998) 237–245.

7 Yehuala T Z, *Development and Evaluation of Electro Mechanical Seed Metering Device for Raised Bed Planter*, M. Tech Thesis, Univ Agric Sci, Raichur, Karnataka, India, 2012.

8 Gautam P V, Kushwaha H L, Kumar A & Kushwaha D K, Mechatronics application in precision sowing: A review. *Int J Curr Microbiol Appl Sci*, **8(04)** (2019) 1793–1807.

9 Modi R U, Manjunatha K, Gautam P V, Nageshkumar T, Sanodiya R, Chaudhary V, Murthy G R K, Srinivas I & Rao C S, Climate-smart technology based farm mechanization for enhanced input use efficiency, Director, ICAR-NAARM, Hyderabad-500 030, (2020).

10 Rajaiah P, Mani I, Kumar A, Lande S D, Parray R A, Singh A K & Vergese C, Comparative Study of Mechanical and Electronic Paddy Planter for Direct Seeding. *Int J Curr Microbiol App Sci*, **7(09)** (2018) 1284–1294. doi: https://doi.org/10.20546/ijcmas.2018.709.153.

11 Bansal N K and Mukesh S, Tractor operated Bt. Cotton planter (Inclined plate with Cell) (Success tories) published by Coordinating Cell AICRP on Farm Implements and Machinery Central Institute of Agricultural Engineering NabiBagh, Berasia Road Bhopal-462 038, India Extension Bulletin No. CIAE/FIM/2010/83, (2010).

12 Sharma V K, Sharma D N & Kumar D, Development and evaluation of tractor drawn inclined cell plate type Bt cotton planter, *Int J Agric Eng*, **6(2)** (2013) 329–334.

13 Cay A, Kocabiyik H & May S, Development of an electro-mechanic control system for seed-metering unit of single seed corn planters Part I: Design and laboratory simulation. *Comput Electron Agric*, **144** (2018) 71–79.

14 Zaman I, Ali M, Shahzad K, Tahir M S, Matloob A, Ahmad W, Alamri S, Khurshid M R, Qureshi, M M, Wasaya A, Baig K S, Siddiqui M H, Fahad S, & Datta R, Effect of plant spacings on growth, physiology, yield and fiber quality attributes of cotton genotypes under nitrogen fertilization, *Agronomy*, *11* (2021) 2589, https://doi.org/ 10.3390/ agronomy11122589.

15 Singh K, Agrawal K N, Dubey A K, and Chandra M P, Development of the controller based seed cum fertilizer drill,*12th Inter Conf Intel Syst Design Applic (ISDA)*, (2012) 369–374, https://doi.org/10.1109/ISDA.2012.6416566.

16 Leela C & Saravanakumar M, Development of electronically meterized maize planter, *Int J Curr Microbiol App Sci*, **8(04)** (2019) 2432–2440.

17 Sahu G, *Development and Evaluation of Simultaneous Seed Dropping Mechanism for Planter*, M Tech thesis, IIT Kharagpur, India, 2016.

18 Mohsenin N N, *Physical Properties of Plant and Animal Materials*, **2nd edn**, (Gordon and Breach Science Publications, New York) 1986, 152–176.

19 Abhyankar S P, Anantachar M, Nageshkumar T, Prakash K V & Rao S A, development of a power tiller-operated inter-row planter for cowpea in cotton strips, *Agri Res*, **12(3)** 2023 1–11.

20 ISO (1984) *ISO 7256/1–1984(E): Sowing Equipment-Test Methods E Part One, Single Seed Drills (Precision Drills),* International Organization for Standardization.

21 IS 6813-2000 *Sowing Equipment-Seed-Cum-Fertilizer Drill-Specification* (second revision), Bureau of Indian Standards, New Delhi, India.

22 IS- 9164-1979: *Guide for Estimating Cost of Farm Machinery Operation*, Indian standards institution Govt. of India, New Delhi,1-17.

23 Anonymous, Package of Practice. Published by Univ. Agric. Sci., Raichur, Karnataka., (2022) 203–224.