Mechatronics Application in Precision Sowing: A Review

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A B S T R A C T

In agriculture profession high output is demanded with limited resources and machines are the costlier investment to the agriculture for a marginal and poor farmer. The accuracy and precision of an agricultural machine can be increased using the electronics and computing systems however it increases the cost of the machines. In spite of costlier investments, many researchers have been conducted the study on mechatronics application in precise sowing operation in recent years. Mechanical planters have problems of ground wheel skidding and vibration in the mechanical transmission that affect the hill to hill spacing. From the review, it was concluded that the mechatronic driving system performed better than mechanical driving system in both tilled and non-tilled fields. The increase in uniformity of seed placement was also reported. Thus, mechatronics based seed placement technique was found a better way to achieve accurate seed spacing with higher efficiency in planting. This paper reviews on the mechatronics and its application in precision planting.

Keywords
Precision agriculture, Mechatronics, Electronics, Computing system, planter

Introduction

There are different methods such as broadcasting, dibbling, sowing behind country plough, seed drill and pneumatic planting for seed placement. Out of these methods, seed drill and pneumatic planting methods are more precise. Seed singulation capability of pneumatic planter is higher however it requires more energy. Seed drilling is most common method for cereals and pulse crops. In seed drill different type of metering mechanism are used for seed singulation. The seed drills are modified with seed metering mechanism for more precise singulation. These machines are called planter. Different types of seed mechanism are used for singulation in planter. These are variable orifice, fluted roller, internal double run, inclined plate and cup feed type. These mechanisms generally require ground wheel for transmission of the power. Due to load on ground wheel for power transmission to metering mechanism, the ground wheel skidding is observed. This skidding is responsible for non-uniform seed placement. Nowadays, agriculture requires new monitoring and control equipment and
embedded systems for agricultural tractors and implements. The concept of intelligent instruments is one of the key reasons for this trend: instruments with embedded microprocessors providing the capabilities of self-calibration, self-diagnosis and local analog-to-digital and digital-to-analog conversion. The digital transmission of data also increases reliability due to automatic error detection and correction. These distributed systems are composed of several devices like sensors, actuators, control elements and supervision and control units, all of them intercommunicating in real time. To overcome ground wheel skidding, research on electronics based seed metering mechanism in planters and seed drills has been done for precise placement of seeds during planting.

Further drawbacks of the mechanical metering devices are the bulkiness of the system and vibrations that are induced on the planter or seed drill as it travels through the field. The final drawback of the mechanically driven system is the lack of communication of seed placement between row units on an implement. On current metering designs, the system has control over only the seeding population, but not the actual timing and placement of the seed. This means a seed is dropping into the furrow at a constant rate, but the row unit cannot detect the time and place where a seed is being placed relative to its neighbouring row units. Therefore, electronically controlled seed singulation devices can address many of the inefficiencies experienced in a mechanically driven seed metering device and have the potential to increase productivity and yield rates dramatically.

**Working principle and components of mechatronics sowing system**

The mechatronics mechanism works on the principle that shaft encoder senses the forward speed and transmit signals in the digital code to the microcontroller. The microcontroller synchronizes the forward speed of operation into 1:1 transmission ratio with the metering mechanism plate. The microcontroller transmits signals to motor driver module and driver connected to electric motor which rotate seed plate of the metering mechanism (Fig. 1).

He et al., (2017) designed a mechatronic system for four row planter consists of seed box, touch screen display, shaft encoder to measure travel speed, electric motors, seed meters, and power supply (Fig. 2). A twelve volt tractor battery provides power for the Mechatronics system. The value of travel speed is measured by an incremental encoder that is mounted on the shaft of a ground wheel. With the rotation of the ground wheel, the encoder outputs corresponding pulses from which the controller can calculate travel speed by measuring the number of pulses received within a given time. The drive motors are brushless DC motors, each with three Hall-effect sensors mounted in the back for measuring the positions of the U, V, and W rotors, which realizes current switching for the rotors. Simultaneously, the three Hall-effect sensors measure the motor speed in real time to achieve closed loop control. A touch screen display allows the entry of parameters such as seed spacing, wheel slip ratio, diameter of the ground wheel, and number of seed holes per disk, displays travel speed, and seed plate rotation speed, and sounds alarms to warn of system malfunction. The controller main functionality is to output a pulse signal with a given frequency and duty cycle to control seed plate rotation speed based on travel speed to achieve uniform seed spacing.

**Trends of mechatronics in sowing**

As one of the trends of development on automation and intelligence of agricultural machinery in the 21st century, all kinds of agricultural robots have been researched and
developed to implement a number of agricultural production in many countries, such as picking, harvesting, weeding, pruning, planting, grafting, agricultural classification, etc. Application of electronics in agriculture has come with the technological advancement. The microcontroller or microprocessors for control of electronic circuitry are now economical and powerful tool with very low error margin as well as testing whether any machine operates in the right adjustment or not.

Not only the hardware but also open source user friendly software has been developed. This has encouraged researcher for specific electronics application in agriculture. The microcontroller can be used as per the need for actuation and sensing. The sensors are used by the researchers for seed placement for depth and distance control (Panning et al., 2000; Lan et al., 1999). Using electronics for metering mechanism may be one of the options to achieve accurate seed spacing with higher efficiency. Sensors can be used in precision planting if integrated with seed metering mechanism. A summary of mechatronics studies in seed sowing focusing on many different aspects is presented below in Table 1, 2, 3, 4 and 5.

**Performance parameters related to precision planter**

The sowing uniformity of seed distribution along the length of the row was analysed using the methods described by Kachman and Smith. Miss index (MI) is the percentage of seed spacings that are greater than 1.5 times the nominal seed spacing and indicates the percentage of missed seed locations or skips. Quality of feeding index (QFI) is the percentage of seed spacings that are more than half but no more than 1.5 times the nominal spacing and indicates the percentages of single seed drops. Precision index (PREC) 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. The calculation formulas for MI, QFI and PREC (Gautam, 2017) are as follows:

\[
QFI = \frac{n'}{N}
\]

\[
MI = \frac{n''}{N}
\]

\[
PREC = \frac{S}{\bar{x}^n}
\]

\[
MULT = \frac{S}{N}
\]

Where,

\[
S = \sqrt{n} \sum_{i=1}^{n'} (x_i - \bar{x})^2
\]

\[
\bar{x} = \frac{1}{N} \sum_{i=1}^{N} x_i
\]

\[x_i\] is the n\textsuperscript{th} seed spacing

\[N = \text{Total number of seed spacings, and} \]

\[n' = \text{Number of spacings in the region greater than 1.5 times of the theoretical spacing} \]

\[n'' = \text{Number of spacings between 0.5 times the theoretical spacing and 1.5 times of the theoretical spacing} \]

\[n = \text{Number of spacing’s in the region less than or equal to 0.5 times of the theoretical spacing} \]

Suggested upper limit of PREC index for single seed planter is 29% (Nejadi and Raoufat, 2013; Raoufat and Mahmoodieh, 2005). Planting performance indicators were evaluated by using the criteria provided in Table 6 (Aykas et al., 2013; ISO 7256/1-1984(E) Standard, 1984; Önal et al., 2012).
Table.1 Mechatronics in seed drill

| S/N | Researcher Name | Seed | Research Topic | Electronic Components | Source | Address of Researcher | Journal Name |
|-----|-----------------|------|----------------|-----------------------|--------|-----------------------|--------------|
| 1.  | M. Jafari, A. Hemmat and M. Sadeghi | Wheat | Development and Performance Assessment of a DC Electric Variable-Rate Controller for Use on Grain Drills. | DC motor, encoders(E50S-2500-3-2-24 and ISE-200-5V), GPS receiver, pulse-with-modulation (PWM) DC motor controller, laptop, 12–24V supply, 12-step CMOS4040 IC, A 74LS138 IC, PID controller, MOSFET, 74LS373 IC | Jafari et al., (2010) | Department of Farm Machinery, College of Agriculture, Isfahan University of Technology, Isfahan 84156-83111, Iran. ahemmat@cc.iut.ac.ir | Computers and Electronics in Agriculture |
| 2.  | Caner Cuhac, ReinoVirrankoski, Petri Hanninen, Mohammed Elmusrati, HermannHoopenka and HeikkiPalomaki | Rye, Wheat, Barley, Corn and Oat | Seed Flow Monitoring in Wireless Sensor Networks. | LED, Light Dependent Resistors (LDR), receiver UWASA Node, ultrasonic and microwave sensor, SURFbuttons, SPI bridge, LCD display, transmitter, battery | Cuhac et al., (2012) | University of Vaasa Department of Computer Science Communications and Systems Engineering Group P.O.Box 700, FI-65101 Vaasa, Finland | Workshop on Wireless Sensor Systems |
| 3.  | HifjurRaheman and Rajeev Kumar | Wheat and Ragi | An Embedded System for Detecting Seed Flow in the Delivery Tube of a Seed Drill | 12 V DC battery, DC motor, potentiometer, DC motor driver, microcontroller (ArduinoNano), IR sensor and buzzer | Raheman& Kumar, (2015) | Agricultural and Food Engineering Department, IIT, Kharagpur, India | Proceeding of International Conference on ACBEE |
| 4.  | S. Kamgar, F. Noei-Khodabadi and S.M. Shafaei | Wheat | Design, Development and Field Assessment of a Controlled Seed Metering Unit to be used in Grain Drills for Direct Seeding of Wheat | digital encoder (Autonics E50S8-1000), variable-rate DCM (model: D12-8001-45W), 4x4 matrix keyboard, Programmable PLC/PMW controller, 16 x2 LCD, PATA cable, PID controller, direct current voltage transducer | Kamgar et al., (2015) | Department of Biosystems Engineering, College of Agriculture, Shiraz University, Shiraz 71441-65186, Iran. smshafaei@shirazu.ac.ir | Information Processing in Agriculture |
| 5.  | SörenKirkegaard Nielsen, Lars JuhlMunkholm, Mathieu Lamandé, Michael Nøremark, Garet T.C. Edwards and Ole Green | Spring Barley | Seed Drill Depth Control System for Precision Seeding | Linear position sensors TX2, P43 ultrasonic height sensors, ultrasonic sensors, X20 controller, electrohydraulic 4/3 oil direction valve SV08-47B, GNSS BT-Q1000XT and pilot-controlled leak-proof | Nielsen et al., (2018) | Aarhus University, Faculty of Science and Technology, Department of Engineering, Denmark | Computers and Electronics in Agriculture |
| 6.  | Karan Singh, K. N. Agrawal and Anurag Kumar Dubey | Soybean | Development of the Controller based Seed cum Fertilizer Drill | Programmable PLC/PMW controller, inductive proximity sensor, AC motor, 24V DC motor, SMPS, encoder, USB, RS-232 and flash card | Singh et al., (2012) | ICAR-CIAE, Bhopal, India. kssingh@ciae.res.in | 12th International Conference on IEEE |
| 7.  | HadiKarimi, HosseinNavid and AsgharMahmoudi | Wheat, corn and pelleted tomato | Online laboratory evaluation of seeding-machine application by an acoustic technique | Microphone (VM-034CY), sound card (Intel® 82801 BA/BAIM AC®97 Audio controller), MATLAB software | Karimi et al., (2015) | University of Tabriz, Faculty of Agriculture, Department of Agricultural Machinery, Tabriz, Iran hadiekarimi@gmail.com | Spanish Journal of Agricultural Research |
| S/N | Researcher Name | Seed | Research Topic | Electronic Components | Source | Address of Researcher | Journal Name |
|-----|----------------|------|----------------|----------------------|--------|----------------------|--------------|
| 8.  | D. E. Wilkins and D. H. Lenker | Lettuce | A microprocessor-controlled planter | 8080 microprocessor, LED, phototransistor, power source and solenoid air valve | Wilkins and Lenker, (1981) | USDA SEA-AR, Columbia Plateau Conservation Research Centre, Pendleton (US) | Transactions of the ASAE |
| 9.  | P. R. Shinde, A. B. Lende, S.V. Rane, S. A. Nawale, M. S. Patwardhan, and L. V. Gharate | Groundnut | Development and Functional Test of Electronic Metering Mechanism for Bullock Drawn JyotiMulticrop Planter. | Opto-isolator sensors, microcontroller (ATMEL89), BC547 and SL100 transistors, 2x16 LCD, solenoid switches, 12V battery and keyboard. | Shinde et al., (2009) | Department of Farm Machinery and Power, Dr. A. S. College of Agricultural Engineering, Mahatma PhuleKrishiVidyapeeth, Rahuri - 413 722, India. | International Journal of Agriculture Environment and Biotechnology |
| 10. | Lianning Xia, Xiangyou Wang, Duanyang Geng and Qingfeng Zhang | Maize and wheat | Performance Monitoring System for Precision Planter Based on MSP430-CT171 | IR LED, phototransistor, photoelectric sensor, LM339, microcontroller (MSP430-CT171), display module (LMC240128ZK), LCD, Bluetooth module, FS-BT485A serial adapter, RS232, Buzzer, Stepper motor, motor driver, keyboard circuit and power driver | Xia et al., (2010) | School of Agricultural and Food Engineering, Shandong University of Technology Zibo, Shandong, China | International Conference on Computer and Computing Technologies in Agriculture |
| 11. | M. Anantachara, Prasanna G.V. Kumar and T. Guruswamy | Peanut | NN Prediction of Performance Parameters of an Inclined Plate Seed Metering Device and Its Reverse Mapping for the Determination of Optimum Design and Operational Parameters | Opto-electronic seed counter, electric motor , ANN models | Anantachara et al., (2010) | Department of Farm Machinery, College of Agricultural Engineering, University of Agricultural Sciences, Raichur 584101, Karnataka, India | Computers and Electronics in Agriculture |
| 12. | O. Hajahmed, E. Tola, K. A. Al-Gaadi and A. F. Kheiralla | Chickpeas seeds | Development of an Opto-Electronic Monitoring System for Crop Planter Seed Metering Unit | AC motor (220 Volt, 0.4 kW), Digital Fiber Sensor (E3X-DA-S), rotary encoder (E6B2- CWZ6C), microcontroller (Atmel ATmega16L) | Hajahmed et al., (2011) | Precision Agriculture Research Chair (PARC), College of Food and Agricultural Sciences, King Saud University, P.O. Box 2460, Riyadh 11451, Saudi Arabia | Middle-East Journal of Scientific Research |
| 13. | T. P. Singh and D. M. Mane | Okra | Development and Laboratory Performance of an Electronically Controlled Metering Mechanism for Okra Seed | Proximity sensor, pulse generator, BCD counter(IC 4510), Timer (IC 4093), Relay unit, DC motor, 12V tractor battery, screw control knob. | Singh and Mane, (2011) | Farm machinery and Power Engineering College of Technology G. B. Pant University of Agriculture and Technology Pantnagar-263145, Uttarakhand INDIA tpSingh_62@yahoo.co.in | Agricultural Mechanization in Asia, Africa, and Latin America |
| 14. | H. Navid, S. Ebrahimian, H. R. Gassemzadeh and M. J. Mousavinia | Pelleted tomato seeds | Laboratory Evaluation of Seed Metering Device using Image Processing Method | Digital camera (Nikon, D70), USB port and MATLAB software | Navid et al., (2011) | Department of Agricultural Machinery Engineering, University of Tabriz, Tabriz, I.R. Iran navid@tabrizu.ac.ir | Australian Journal of Agricultural Engineering |
| 15. | Tejminder Kaur and Dilip Kumar | Wheat | Design and Development of Calibration Unit for Precision Planter. | Frame light barrier sensor, Proximity sensor (gear tooth sensor), SMU, 1 hp AC motor, Yaskawa J1000 AC drive, RS232 and USB communication | Kaur& Kumar, (2013) | Centre for Development of Advanced Computing(C-DAC), Mohali, India | International Journal of Computer Science, Engineering and Applications |
|   | Authors | Title | System Details | Reference Details |
|---|---------|-------|----------------|-------------------|
| 16. | Du Ruicheng, Gong Bingcai, Liu Ningning, Wang Chencen, Yang Zidong and Ma Mingjian | Design and Experiment on Intelligent Fuzzy Monitoring System for Corn Planters | On-board computers, GPS receivers, digital cameras, tilt sensor, USB-CAN interface module, displacement sensors, electronically controlled stepless spacing regulator, CAN bus analog input module, CAN bus digital input and output modules, CAN bus pulse counting module, seed tank sensor, fertilizer tank sensor, seeding orifice sensor and gear speed sensor | Ruicheng et al., (2013) School of Agriculture and Food Engineering, Shandong University of Technology, Zibo 255049, Shandong, China. International Journal of Agricultural and Biological Engineering |
| 17. | Javad Taghinezhad, Reza Alimardani and Ali Reza Jafari | Design a Capacitive Sensor for Rapid Monitoring of Seed Rate of Sugarcane Planter | Rectangular parallel plate capacitor, electronic circuitry, microcontroller, and display unit | Taghinezhad et al., (2013) Department of Agricultural Machinery Engineering, Faculty of Agricultural Engineering and Technology University of Tehran, Iran. Agricultural Engineering International: CIGR Journal |
| 18. | Margarita Velandia, Michael Buscher Mohile, James A. Larson, Nathanael M. Thompson, Brandon Michael Jernigan | The economics of Automatic Section Control Technology for Planters: A Case Study of Middle and West Tennessee Farms | GPS receiver (Trimble EZ-Guide 500 system), GPS antenna (Trimble AgGPS 25 antenna), Intercom RTK Bridge cellular modem, netbook computer, data logger and switches | Velandia et al., (2013) Department of Agricultural and Resource Economics, The University of Tennessee, Knoxville, TN, United States. Computers and Electronics in Agriculture |
| 19. | Zhai Jianbo, Zhao Junfang, Zhou Yong and Zhang Shun | Design and Experimental Study of the Control System for Precision Seed-Metering Device | Hall sensor, AT89S51 single chip microcomputer, Motor control module, 57H76-03 stepper motor and adjustable speed motor | Jianbo et al., (2014) College of Engineering, Huazhong Agricultural University, Wuhan430070, Hubei Province, China. IJABE |
| 20. | V. V. Aware and S. V. Aware | Development of Microprocessor based Electronic Metering Mechanism for Seed—an Approach | Microcontroller (AT89C51 IC), inverter, D.C. motor, operational amplifier (LM741), 2 X 16 LCD Display, tactile switches, 12 MHz crystal oscillator, Capacitors, Diodes, opto- electric sensor, 230 V, 50 Hz A.C supply, Transformer | Aware & Aware, (2014) Department of Farm Machinery and Power, College of Agricultural Engineering and Technology, Dr. B.S. Konkan Krishi Vidyapeeth, Dapoli, RATNAGIRI (M.S.), INDIA. Engineering and Technology in India |
| 21. | Cristian Iacomi and Octavian Popescu | A New Concept for Seed Precision Planting | Linear solenoid actuator, Optoelectronic sensor (IR LED, phototransistor) and electronic switch | Iacomi & Popescu, (2015) University of Agronomic Sciences and Veterinary Medicine of Bucharest, 59 Marasti Blvd, 011464, Bucuresti-1, Romania. Agriculture and agricultural science proceedings |
| 22. | Niu Kang, Fang Xianfa, Liu Yangchun, Li Chengxu and Yuan Yanwei | Optimized Design and Performance Evaluation of an Electric Cup-Chain Potato Metering Device | Microcontroller (PIC18F2580), motor control circuit, GPS, D/A translate box, servo motor, differential GPS, RS232 serial port, PID control algorithm, servo motor (SGMV-04ADE6S), servo driver (SGDV-2R8A01B00200) analysis software DPS v7.05 and Matlab R2012A | Kang et al., (2017) College of Engineering, China Agricultural University, Beijing 100083, China yyw215@163.com. International Journal of Agricultural and Biological Engineering |
| 23. | Shankha Koley, Y. C. Bhatt, Gajendra Singh, Sunil Joshi and H. K. Jain | Development of Electronic Metering Mechanism for Precision Planting of Seeds | Proximity sensor, microcontroller (AT89C51), motor driver (L293D), DC motor, potentiometer (150 W) and power source | Koley et al., (2017) Indian Institute of Technology, Kharagpur, India. International Journal of Current Microbiology and Applied Sciences |
### Table 3: Mechatronics in Pneumatic Planter

| S/N | Researcher Name | Seed | Research Topic | Electronic Components | Source | Address of Researcher | Journal Name |
|-----|-----------------|------|----------------|-----------------------|--------|-----------------------|--------------|
| 24  | Y. Lan, M. F. Kocher and J. A. Smith | Sugar beet and pelleted chicory | Opto-electronic Sensor System for Laboratory Measurement of Planter Seed Spacing with Small Seeds | NIR LEDs (EG and G VACTEC GaAs VTE3322LA), phototransistors (EG and G VACTEC NPN VTT3323LA), digital input/output (I/O) board, opto-electronic sensor, Hall-effect switch, 2.58 MHz clock, data-acquisition program | Lan et al., (1999) | Department of Biological Systems Engineering, University of Nebraska, Lincoln, NE 68583, USA | Journal of Agricultural Engineering Research |
| 25  | Zeliha Bereket Barut and Kadir Yiğit | Corn | Design of Electronic-Based Measurement System for Seed Spacing Measurement in Precision Planters | Microcontroller (AT89S8252), fiber-optic sensor amplifier, 2 fiber-optic sensors and 2 mutual fiber-optic cables, analog-digital converter, electrical motor. | Barut & Yiğit, (2008) | Çukurova University, Faculty of Agriculture, Department of Agricultural Machinery, 01330, Adana, Turkey | 10th International Congress on Mechanization and Energy in Agriculture |
| 26  | Okan Önal and Ismet Önal | Hybrid maize and cotton | Development of a Computerized Measurement System for In-Row Seed Spacing Accuracy | CMS hardware, laser pointer, notebook computer, optical mouse (Microsoft Optical Mouse 3000), USB cable extension, Light meter (Lutron model Lx-1108) and CMS software | Önal & Önal, (2009) | Dokuz Eylül University, Department of Civil Engineering, Kaynaklar Yerleşkesi, Buca, İzmir – TURKEY. okan.onal@deu.edu.tr | Turkish Journal of Agriculture and Forestry |
| 27  | Saadat Kamgar and Mohammad J. Eslami | Corn | Design, Development and Evaluation of a Mechatronic Transmission System for Upgrading Performance of a Row Crop Planter | 45W DC motor, tractor battery (12V&75Ah), microcontroller, MOSFET, potentiometer, rotary shaft encoder (E50S8-1000), 4x4 matrix keyboard and 2x16LCD | Kamgar & Eslami, (2012) | Agricultural Engineering Department, Shiraz University, Shiraz, Iran. kamgar@shirazu.ac.ir | American Society of Agricultural and Biological Engineers |
| 28  | Saadat Kamgar, Mohammad Javaad Eslami and Mohammad Mehdi Mahfarzouie | Corn | Design, Development and Evaluation of a Mechatronic Transmission System to Improve the Performance of a Conventional Row Crop Planter | 45W DC motor, tractor battery (12V&75Ah), microcontroller, MOSFET, potentiometer, rotary shaft encoder (E50S8-1000), 4x4 matrix keyboard and 2x16LCD | Kamgar et al., (2013) | Agricultural Engineering Department, Shiraz University, Shiraz, Iran. kamgar@shirazu.ac.ir | International Journal of Agronomy and Plant Production |
| 29  | Qi Jiangtao, Jia Honglei, Li Yang, Yu Haibo, Liu Xinrui, Lan Yubin, Feng Xianzhen and Yang Yongxi | Corn | Design and Test of Fault Monitoring System for Corn Precision Planters | Capacitive sensors (TAP-3040N1-D3 model), Display module (J160128BLCD), matrix keyboard, single-chip microcomputer (STC12C5A60S2), alarm module, input mode, count chip (74LS590), encoder (PH8S-3600-G05L) and 8255A chip. | Jiangtao et al., (2015) | Key Laboratory of Bionic Engineering (Ministry of Education), Jilin University, Changchun 130022, China | International Journal of Agricultural and Biological Engineering |
| 30  | Yang Li, He Xiantao, Cui Tao, Zhang Dongxing, Shi Song, Zhang Rui and Wang Mantao | Corn | Development of Mechatronic Driving System for Seed Meters Equipped on Conventional Precision Corn Planter | Two-phase hybrid stepper motor (57HBP76AL4-TF0), tractor battery, driver module (2HD403), rotary shaft encoder (TRD-2T500BF), touchscreen (MT4414T), RS485 and microcontroller (STM32F103VCT6) | Li et al., (2015) | College of Engineering, China Agricultural University, Beijing 100083, China zhangdx@cau.edu.cn | International Journal of Agricultural and Biological Engineering |
| 31  | Habib Kocabiyik, Anil Cay, Bilal Karaaslan, Sahin May and M. Khurelbaatar | Corn | Electro-mechanic Control System for Pneumatic Precision Corn Planters | ESC (electronic speed controller), driver module, DC electric motors, encoders, cables connectors .PWM and PID techniques | Kocabiyik et al., (2016) | Canakkale Onsekiz Mart University, Faculty of Agriculture, Department of Agricultural Machinery and Technologies Engineering, 17020, Canakkale, Turkey. | International Conference on Machine Control and Guidance |
| 32  | Devin L. Mangus, | Corn | Development of High-Speed Borsch Terminal ME controller, radar | Mangus et al., | Biological and Agricultural Computers and | | |
| S/N | Researcher Name                  | Seed               | Research Topic                                                                 | Electronic Components                                                                 | Source                     | Address of Researcher                  | Journal Name                        |
|-----|---------------------------------|--------------------|--------------------------------------------------------------------------------|----------------------------------------------------------------------------------------|---------------------------|----------------------------------------|--------------------------------------|
| 33  | X. He, T. Cui, D. Zhang, J. Wei, M. Wang, Y. Yu, Q. Liu, B. Yan, D. Zhao and L. Yang | Corn               | Development of an Electric-Driven Control System for a Precision Planter Based on a Closed-Loop PID Algorithm | Display (MT4414T), incremental encoder (TRD-2T500BF), four drive motors, 12V tractor battery, Hall-effect sensors, Optical Coupler (PC357), RS232 Transceiver (MAX232), Main Controller (STM32F103VCT6), Auxiliary Controller (STM32F103RBT6) and power MOSFET | He et al., (2017)           | College of Engineering, China Agricultural University, Beijing 100083, China. yl_bb8@126.com | Computers and Electronics in Agriculture |
| 34  | Yongliang Hao, Tao Cui, Ganesh Bora, Dongxing Zhang, Jiantao Wei, Xiantao He, Mantao Wang and Li Yang | Corn               | Development of an Instrument to Measure Planter Seed Meter Performance            | Servo motor and gearbox, motor driver, seed sensor, PLC controller (CPUS04EX), table computer and printer (J625DW) | Hao et al., (2017)          | College of Engineering, China Agricultural University, Beijing 100083, China. yangli@cau.edu.cn | Applied Engineering in Agriculture      |
| 35  | Anil Cay, Habib Kocabiyik and Sahin May | Corn               | Development of an electromechanical control system for seed-metering unit of single seed corn planters Part I: Design and laboratory simulation | Control panel, processor, electronic speed controller, driver module, brushless DC electric motors and other Supplementary elements such as encoders, cables and connectors | Cay et al., (2018)       | Department of Agricultural Machinery and Technologies Engineering, Faculty of Agriculture, Canakkale Onsekiz Mart University, Canakkale, Turkey | Computers and Electronics in Agriculture |
| 36  | Anil Cay, Habib Kocabiyik and Sahin May | Corn               | Development of an Electro-Mechanical Control System for Seed-Metering Unit of Single Seed Corn Planters Part II: Field Performance | Control panel, processor, electronic speed controller, driver module, brushless DC electric motors and other Supplementary elements such as encoders, cables and connectors | Cay et al., (2018)       | Department of Agricultural Machinery and Technologies Engineering, Faculty of Agriculture, Canakkale Onsekiz Mart University, Canakkale, Turkey | Computers and Electronics in Agriculture |

**Table 4. Mechatronics in Magnetic Planter and Trans-Planter**
### Table 5 Seed Sowing Robot

| S/N | Researcher Name                          | Seed                                      | Research Topic                                                                 | Electronic Components                                                                 | Source                                                                 | Address of Researcher                                                                 | Journal Name                                                                 |
|-----|------------------------------------------|-------------------------------------------|--------------------------------------------------------------------------------|---------------------------------------------------------------------------------------|-------------------------------------------------------------------------|--------------------------------------------------------------------------------|--------------------------------------------------------------------------------|
| 40. | M. Priyadarshini and L. S. Belsare        | Command based Self-Guided Digging and Seed Sowing Rover | DC motor, Ultrasonic Radar sensor, sowing control sensor, relay driver circuit, Wireless controller, PC, Bluetooth module, Battery package, Arduino mega2560 microcontroller and LCD module | Priyadarshini & Sheela, (2015)                                                    | Dept of EEE, Embedded System Technologies Regional office: Anna University Tirunelveli, India | sambare.swati@gmail.com                                                            | International Conference on Engineering Trends and Science and Humanities  |
| 41. | Swati D. Sambare and S. S. Belsare        | Use of robotics technology for seed sowing in Agriculture | Keyboard, Zigbee module, PC, IR sensor, L293D driver module, DC Motor, stepper motor, UNL2803, LCD, LPC2148 microcontroller, MAC layers | Sambare & Belsare, (2015)                                                          | Dept. of Electronics, BVDUCOEP, Pune, India                             |                                                                                 | IJSRM                                                                           |
| 42. | Lin Haibo, Dong Shuliang, Liu Zanmin and Yi Chujie | Wheat                                    | Study and Experiment on a Wheat Precision Seeding Robot                      | Drive motor, Steer motor, Seeding motor, Motor driver, Motor controller, Controller, PC, Lead-acid Batteries, sensor for pressure and speed | Haibo et al., (2015)                                                  | College of Mechanical Engineering, Qingdao Technological University, Qingdao 266520, China | Journal of Robotics                                                              |
| 43. | Neha S. Naik, Virendra V. Shete and Shruti R. Danve | Cotton, Maize, Soybean and Wheat         | Precision Agriculture Robot for Seeding Function                             | Power supply (9 and 12 V DC), input switches, IR sensors, relays, 16x2 LCD display, DC motors, motor driver (L293D IC), ARM7 board, microcontroller (LPC2148) | Naik et al., (2016)                                                | Department of E and TC, MITCOE, Pune, India                                      | International Conference on IEEE                                                    |
| 44. | Kiran AS and Baban Parisa Dathwade        | Design and Fabrication of Automatic Seed Sowing Machine with Variable Pitch | Microcontroller, DC Gear Motor, rotary encoder, Battery, Keypad               | Kiran & Dathwade, (2016)                                                           | Department of Mechanical Engineering, BCE, Shravanabelagola, India       | kiran.as.april92@gmail.com                                           | European Journal of Advances in Engineering and Technology                        |
| 45. | Palepu V. Santhi, Nellore Kapilieswar, Vijay K. R. Chenchela and Venkata Siva Prasad. CH | Sensor and vision based autonomous AGROBOT for sowing seeds | Controller (Arduino), Ultrasonic and IR sensors, vision sensor, power supply, PC | Santhi et al., (2017)                                                           | Department of Electrical, Electronic and Computer Engineering, University of Pretoria, South Africa |                                                                                 | ICECDS                                                                          |
| 46. | Anuja Mohalkar, Priti Mohite, Shubhangi Nagare, and Sampada Tavse | Automatic Seed Sowing Machine using Solar Panel | Microcontroller (PIC16F877A), Keypad, LCD, DC Motor Driver (L293D), IR Sensor, DC motors, 12V battery, amplifier, buzzer, keypad and solar panel | Mohalkar et al., (2017)                                                          | Department of E and TC Engineering, MarathwadaMitraMandal's College of Engineering, Pune, India | anujamohalkar@gmail.com                                                            | International Journal of Innovations in Engineering Research and Technology      |
| 47. | Rohan Chauhan                            | Electronic Demarcation Technique for Robotic Precision Planter | Microcontroller (Arduino Mega), DOF IMU, rotary encoder, stepper motors, sensors, raspberry Pi3, Camera, motor board, battery, power bank, DC-DC converter and Ubuntu MATE | Chauhan, (2017)                                                                 | Kalinga Institute of Industrial Technology, School of Computer Engineering, Bhubaneswar, Odisha, India. |                                                                                 | Journal of Engineering and Applied Sciences                                      |
| 48. | T. V. Pavan, R. Suresh, K. R. Prakash, and C. Mallikarjuna | Green gram                              | Design and Development of Agrobot for Seeding                                | 12V DC geared motors, Arduino Uno board, Atmega32 microcontroller, motor driver (L298), Voltage regulator785, lead acid battery, Ultrasonic sensor, | Pavan et al., (2017)                                                              | Dept Of Industrial Automation Engineering, VTU PG Studies, Mysuru, Karnataka, India | International Research Journal of Engineering and Technology                       |
| 49. | Shraddha Muley and Warsha S. Kandlikar    | Soybean, Jowar, Wheat and Peanut          | Robotic Vehicle for Seed Planting and Weeding Applications                    | ultrasonic sensor, keypad, LDR, LED, DC motors, motor driver, Arduino Due Board, microcontroller (Atmel SAM3X8E ARM Cortex-M3 CPU), SDA and SCL pins, Due and AVR-based boards, Ultrasonic ranging module HC - SR04 and L293D IC | Muley & Kandlikar, (2017)                                           | Department of Electronics Design and Technology, National Institute of Electronics and Information Technology, Dr. B.A.M. University Campus, Aurangabad India | International Journal for Innovative Research in Science and Technology           |
| 50. | Nikita Chame, Mamta Jadhav, Priyanka Tele and Snehal P. Hon | Design and Implementation of Automatic Seed Sowing Robot | 12V battery, voltage regulator, PID controller, LDR sensor, IR sensor, DC motors driver IC L293D, DC motors, ADC (Atmega28p), Servo motor, Pulse Width Modulation | Chame et al., (2018)                                                             | Department of Electronics and Telecommunication, PES MCOE, Pune, India |                                                                                 | International Journal of Research in Engineering, Science and Management            |
**Table 6** Limit values of performance criteria for precision seeding (Cay *et al.*, 2018)

| QFI (%) | MI (%) | MULT (%) | Classification |
|---------|--------|----------|----------------|
| >98.6   | <0.7   | <0.7     | Very good      |
| >90.4–98.6 | ≥0.7 to<4.8 | ≥0.7 to<4.8 | Good          |
| ≥82.3 to ≤90.4 | ≥04.8 to<7.7 | ≥04.8 to<10 | Moderate      |
| <82.3   | >7.7   | >10      | Insufficient   |

**Table 7** Results Obtained in Different Study with Mechatronics

| Source               | Speed (Kmh⁻¹) | Results  |          |          |          |          |
|----------------------|---------------|----------|----------|----------|----------|----------|
|                      |               | QFI (%)  | MULT (%) | MI (%)   | PREC (%) |
| Cay *et al.*, (2018) | 5 – 10        | 2.91–95.36 | 0–1.73   | 4.45–97.09 | 8.79–22.14 |
| Mangus *et al.*, (2017) | 2.4 -16.1     | 98.45    | 0.2      | 0.8      | ---      |
| Cay *et al.*, (2018) | 5 – 10        | 90.63    | 0.94     | 8.44     | 17.63    |
| Taghinezhad *et al.*, (2013) | 0.9 – 3.6     | 89.72 - 93.43 | 2.52 - 7.23 | 2.81 - 7.26 | ---      |
| Jianbo *et al.*, (2014) | 3.6–7.2      | 85.83 - 95 | 0 - 3.34 | 5 - 10.83 | ---      |
| Jiangtao *et al.*, (2015) | 4.00        | 89.4 - 91.46 | 2.44 -3.86 % | 5.28 - 9.11 | ---      |
| Xiao Yue *et al.*, (2013) | 0.52rad/s.    | 90.28    | 4.69     | 5.04     | ---      |
| Singh and Mane, (2011) | 1 - 3.4      | 100      | 0        | 0        | 1.84 - 7.34 |
| Önal & Önal, (2009) | 1.8 - 7.2    | 91.30    | 2.90     | 5.80     | ---      |
| He *et al.*, (2017) | 8.6 - 13      | 96.9 - 98.81 | ---     | 1.19 - 3.1 | 14.38 - 16.04 |
| Hao *et al.*, (2017) | 3 - 12        | 95.1 - 98.1 | 0.2 - 0.7 | 1 - 4.2  | ---      |
| Kocabiyik *et al.*, (2016) | 5 - 10       | 31.73 - 97.18 | 0 - 0.82 | 2.45 - 69.27 | 9.57 - 14.07 |
| Li *et al.*, (2015) | 9 - 12        | 89.93 - 94.23 | ---     | 2.49 - 5.03 | 17.85 - 18.80 |

**Fig.1** Principle of mechatronics metering mechanism (Jiangtao *et al.*, 2015)
Different studies’ result

It was observed that as the working speed increased, quality of feed index (QFI) of the seed-metering device dropped gradually with increased miss index (MI) and precision index (PREC) as well as deviation from the average seeds spacing became greater. The multiple index (MULT) decreases with increase in speed. The studies were indicated that precision planter equipped with mechatronics system observed good seeding uniformity among all seeding technologies with QFI, MI, MULT and PREC in range of 90-98, 0-11, 0-7 and 1-22 per cent, respectively under travel speed of 1 to 16 km h\(^{-1}\) (Table 7). Thus, mechatronics metering mechanism may be one of the options to achieve accurate seed spacing with higher efficiency in planting/seeding and capable to reduce the effect of higher speed of seeding.

It was observed that mechatronics driving system when attached with pneumatic planter can reduce the effect of forward speed on planting accuracy effectively such as 4-8% increase in QFI and 4-7% decrease in MI.

Mechatronics system solves the problems of existing precision planters like as ground wheel skidding.

Possibility of getting more transmission ratio by changing the pulse width modulation like as variable rate technology.

Good seeding uniformity and high productivity obtained because lowering precision index value of precision index up to 15%.

Agribot gives near about 92% accuracy regarding placement of different type of seeds and it can much more accurate in future.

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