DEVELOPMENT OF MICROCONTROLLER BASED SEED METERING MECHANISM FOR PRECISION PLANTING

PROJECT REPORT

Submitted to

College of Agricultural Engineering and Technology,

Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola

In partial fulfillment of the requirements

for the Degree of

BACHELOR OF TECHNOLOGY

In

Agricultural Engineering

By

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2022-23

DECLARATION OF STUDENT

We hereby declare that the experimental work and its interpretation in the project report entitled **"DEVELOPMENT OF MICROCONTROLLER-BASED SEED METERING MECHANISM FOR PRECISION PLANTING"** or part thereof have neither been submitted for any other degree or diploma of any University, nor the data have been derived from any thesis publication of any University or scientific organization. The source of materials used and all assistance received during the investigation have been acknowledged.

Place:- Akola
Date: / /2023

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CERTIFICATE

This is to certify that the project report entitled **“DEVELOPMENT OF MICROCONTROLLER-BASED SEED METERING MECHANISM FOR PRECISION PLANTING”** submitted in partial fulfillment of the requirement for the degree **of “Bachelor of Technology (Agricultural Engineering)”** of Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola is a record of bonafide research work carried out by **ANISH KUMAR AND SANTOSH PATIDAR** under my guidance and supervision.

The subject of the project has been approved by the project guide.

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Success is not possible lonely without the involvement of many minds and hands to beautify it. Emotion cannot be adequately expressed in words because then emotions are transformed into mere formalities. Nevertheless, formalities must be completed. My acknowledgements are many more than what expressing here.

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TABLE OF CONTENTS

A) LIST OF TABLES

B) LIST OF PLATE

C) LIST OF FIGURES

D) LIST OF ABBREVIATIONS AND SYMBOLS

Abbreviation		Expanded Form
Dr. P.D.K.V.	-	Dr. Panjabrao Deshmukh Krishi Vidyapeeth
C.A.E.T.	-	College of Agricultural Engineering and Technology
Deptt.	-	Department
et al.	-	And others
etc.	-	Etcetera
i.e.	-	That is
gm	-	Gram
kg	-	Kilogram
hac	-	Hectare
kg/ha	-	Kilogram per hectare
kmph	-	Kilometer per hour
mm	-	Millimeter
cm	-	Centimeter
cm^3	-	Cubic centimeter
m	-	Meter
m^2	-	Square meter
km	-	Kilometer
s	-	Second
min	-	Minute
h	-	Hour
ha/h	-	Hectare per hour
km/h	-	Kilometer per hour
m/s	-	Meter per second
BC	-	Benefit-cost
TC	-	Total Cost
Sr.	-	Serial
No.	-	Number

rpm	-	Revolution per minute
MC	-	Moisture Content
%	-	Percent
=	-	Equal to
+	-	Addition
×	-	Multiplication
/	-	Division
°	-	Degree

E) THESIS ABSTRACT

a) Title of the thesis	:	**DEVELOPMENT OF MICROCONTROLLER-BASED SEED METERING MECHANISM FOR PRECISION PLANTING**
b) Full name of student	:	**Anish Kumar** **Santosh Patidar**
c) Name and address of Major Advisor	:	**Dr. A. K. Kamble** Assistant Professor Department of Farm Power and Machinery, Dr. PDKV, Akola.
d) Degree to be awarded	:	B. Tech (Agril. Engg.)
e) Year of award of degree	:	2023
f) Major subject	:	Farm Power and Machinery
g) Total number of pages in the thesis	:	61
h) Number of words in the abstract	:	360
i) Signature of student	:	
j) Signature, Name, and address of forwarding authority	:	

Head

Department of Farm Power & Machinery, Dr. PDKV, Akola

ABSTRACT

The project in title " Development of microcontroller-based seed metering mechanism for Precision planting" was undertaken with to objectives to develop a microcontroller-based single unit of seed metering mechanism for precision planting and evaluate its performance in the laboratory. The precision planting of crops is progressing in the country, however, there are no indigenous precision planting machines available in the country. Some imported substitutes are available but being too costly is beyond the reach of common farmers. Therefore, the development of a prototype through microcontroller metering of seeds would be an indigenous and cost-effective substitute for imported planters. A commercially available vertical plate metering unit is selected for the study. The seed metering plate is operated by a DC motor directly coupled to the shaft of the seed metering plate. The seed-to-seed metering plate was regulated using proximity sensor reading. The metering unit was done by a vertical plate metering unit and was driven by a DC motor whose speed can be easily regulated using a proximity reading. The metering unit was synchronized with the forward speed of the ground wheel with the help of a proximity sensor and microcontroller. The developed metering unit was tested in the laboratory for metering Soyabean seed at various tractor forward speeds of 3, 3.5 and 4.5 km/hr. The seed spacing, miss Index and multiple indexes were calculated over greased seed belt and the results were analyzed. A program was developed in C++ computer language to maintain a seed-to-seed spacing of 9.2 cm of soyabean seed using Arduino uno microcontroller. The plant-to-plant spacing was found to be 10.31, 8.89 and 9.43 cm in the laboratory on a sticky belt at 3, 3.5 and 4.5 km/h respectively. The miss index was also worked out and found to be 21.05, 20 and 21.21 % at 3, 3.5 and 4.5 km/h forward speed respectively. Similarly, the multiple index was determined and found to be 13.11, 20 and 18.18 % at forward speeds of 3, 3.5 and 4.5 km/h respectively. The maximum variation in seed-to-seed spacing was observed 12.06 % at 3 km/h forward speed and a minimum of 2.50% at 3.5 km/h.

Keywords: Vertical seed metering plate, electronic unit, sensor

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CHAPTER I

INTRODUCTION

1.1 Background information

Most of the developing countries of Asia have the problem of high population and low levels of land productivity as compared to the developed nations. The prime reasons for low productivity are insufficient power availability on the farms and a low level of farm mechanization. This is especially true for India as well. India is an agricultural country and is considered to be the backbone of the Indian economy. It contributes about 18 per cent to GDP after engaging 60 per cent of the total population. The major constraints in increasing farm production are low levels of farm mechanization, dry land cultivation, low land holdings, shortage of capital and social factors. Though efforts are being made to mechanize at various levels success has been achieved on a limited scale. Though the country's food grain production reached a record of 241 million tons in 2011, with the increasing population from 121 crores in 2011 to about 138-140 crores in 2022 at the present growth rate, food grain production also to be increased from 240 to 340 million tonnes. (available at www.iari.res.in).

To ensure high production it is required to sow a high-yielding variety of seeds, but without proper placing of seeds timely at desired depths and spacing it is impossible to achieve higher productivity. Precision agriculture is the application of technologies and principles to manage spatial and temporal variability associated with all aspects of agricultural production for the purpose of improving crop performance and environmental quality. Success in precision agriculture is related to how well it can be applied to assess, manage and evaluate the space-time continuum in crop production. Precision agriculture management practices can significantly reduce the amount of nutrients and other crop inputs used while boosting yields. Farmers thus obtain a return on their investment by saving on seeds and fertilizer costs. The second, larger-scale benefit of targeting inputs

In spatial, temporal and quantitative terms concerns environmental impacts. Applying the right amount of inputs in the right place and at the right time benefits crops, soils and groundwater, and thus the entire crop cycle. Consequently, precision agriculture has become a basis of sustainable agriculture, since it respects crops, soils and farmers. Sustainable agriculture seeks to assure a continued supply of food within the ecological, economic, and social limits required to sustain production in the long term. Precision Agriculture, therefore, seeks to use high-tech systems in pursuit of this goal. The precision planting of crops is progressing in the country, however, there are no indigenous precision planting machines available in the country. Some imported substitutes are available but being too costly is beyond the reach of common farmers. Proper placement of seeds can be achieved by the use of planters. Seed drills and planters basically drop seed at a predetermined depth in a row and maintain the seed rate.

1.2 Importance and need of study

For crop production, seeds are normally required to be sown in a well-prepared seed bed, maintaining row-to-row and plant-to-plant spacing. It is also required to drop the seed at the desired depth for perfect germination. Various types of planters and seed drills have been developed but the problem still persists, like missing seeds, overfilling, etc. Electronic planters work with a sensor-based electronic metering system, which adds precision to the work. The sensor system in the machine helps in the proper metering of seeds and thus further reduces the losses. The seed rate can be easily controlled with the rpm controller and can be used for a variety of seeds with a change in the seed metering Plate. To overcome all these problems electronic planters can be of great use with the following advantages taken into consideration.

1. Precision planting of seed.
2. Reduction in wastage of seeds.
3. Elimination of chain and sprocket assembly mounted on ground wheel and seed metering mechanism.
4. Smooth and faster operation.
5. Compact design of seed metering mechanism of the machine.

6. Easy control over adjustments.
7. Efficient working.

Therefore, the development of a prototype using microcontroller-based seed metering would be an indigenous and cost-effective substitute to imported planters.

1.3 Objectives of the study

1. To develop microcontroller-based seed metering mechanism for precision planting.
2. To evaluate performance of the developed microcontroller-based seed metering mechanism in laboratory.

1.4 scope and Limitation of the Study

Electronic-based seed metering mechanisms offer significant advantages in precision seeding, variable rate seeding, real-time monitoring, data collection, and integration with precision agriculture technologies. By providing precise control over the number of seeds planted, these mechanisms ensure uniform seed distribution, resulting in improved crop establishment and higher yields. The ability to program variable seed rates based on field conditions or crop requirements allows farmers to optimize seed placement and density, enhancing overall productivity. Real-time monitoring capabilities enable farmers to closely monitor and adjust planting parameters on the go, ensuring accurate seeding and making immediate corrections if any issues arise. The data collected during the planting process can be analysed to identify trends, optimize planting strategies, and make informed decisions for future plantings. Additionally, the integration of electronic seed metering systems with other precision agriculture technologies facilitates seamless data exchange and coordinated control of planting operations, maximizing efficiency and reducing input waste.

The initial cost of these systems is typically higher than that of traditional mechanical seed meters, which may pose a financial barrier, especially for small-scale farmers. The complexity of electronic systems requires technical expertise for installation, calibration, and maintenance, potentially necessitating training or professional assistance. Reliable power sources are crucial for the operation of electronic systems, which can be challenging to ensure in remote or off-grid areas. Furthermore, electronic components may be sensitive to extreme weather conditions, such as heavy rain, extreme heat, or dust, necessitating protective measures and regular maintenance. Compatibility issues may arise when retrofitting electronic seed metering mechanisms onto older seed planters or equipment, potentially requiring upgrades or replacements. It is essential to consider these limitations when implementing electronic seed metering mechanisms to ensure their successful integration into agricultural practices.

CHAPTER II

REVIEW OF LITERATURE

Literature review revealed that a substantial amount of work on precision planting machinery has been reported but little attention has been paid on development of microcontroller-based seed metering for precision planter. The work of various researchers related to the present study has been reviewed and the finding reported in them are reviewed briefly as under in the following three sections.

1 Electronic metering devices

2 Precision planters

3 Performance evaluation of planters

2.1 Electronic metering devices

Aware *et al.,* (2008) developed an electronic metering mechanism introduced in 3 rows planter and 18 hp garden tractor was used as a power source. Three rows inclined Plate planter consisted of hoppers, frame, ground wheel and power transmission system as main components. The electronic metering mechanism consisted of a proximity distance sensor, ground wheel Plate, 12 V DC battery, 12 V, 42 rpm DC motor, cell Plate etc. as major components. Groove size on the cell Plate was designed using spatial dimensions of cowpea seed. A metering mechanism was designed considering cowpea plant-to-plant spacing as 12 to 13 cm. As per the design, the theoretical plant-to-plant spacing for cowpea seed was 12.58 cm, the number of cells on the cell Plate was 10 and the number of fingers on the ground 9-wheel Plate was 7 having a width of 1.3 cm. The newly developed electronic planter was tested in the laboratory. The average spacing plant to plant spacing for the three rows was 12.35 cm. It was necessary to maintain the tractor speed constant for getting the plant-to-plant spacing as per design.

Benneweis *et al.,* (1993) implemented controller systems for planters and seeders by connecting the sensors and actuators directly to a console unit mounted in the tractor. The communication system, which reduced the number of wires across the tractor-seeder hitch from 22 to 6, was described. This system used a microcomputer-based controller and was designed for the model 2320 and 1720 flexi-coil air seeders.

Karthikeyan (2004) developed an electronic seed monitoring system for planters. The system comprised LED and phototransistors as sensing elements, a detector unit, and a seed flow detector block. A four-digit block was made for counting the number of seeds flowing through the seed tube. As an alternative, a unit with three LEDs and three phototransistor combinations was also developed. The sensor was tested in laboratory as well as in field conditions.

Lan *et al.,* (1999) developed an optoelectronic sensor system for laboratory measurement of planter seed spacing with small seeds. It consisted of a rectangular 8 photo block (124×92 mm) with 24 phototransistors (diameter 3 mm) receiving light beams from 24 LEDs opposite to them, a digital input-output board in a personal computer and power supplies.

Minjin *et al.,* (2003) developed a dibble precision seeder with photoelectric close-loop controls for coated rice seeds. A single-chip microprocessor was used to control the metering mechanism. Test results showed that the efficiency was around 98.5 per cent with a seeding rate of 1.4 per cent and zero missing seeds. Coated rice seeds used for industrialized rice seedling nurseries were favourable for mechanical seeding.

Shinde *et al.,* (2009) develop an electronic metering mechanism for the Jyoti multi-crop planter and test the prototype for sowing groundnut. To achieve this objective a prototype of the planter, consisting of a main frame, fertilizer metering, electronic seed metering and power transmission unit, was developed. Electronic seed metering consists of a distance sensing unit, a chuck valve activating system with a microprocessor, software programmed, and solenoid switches are developed. The prototype was tested for its performance. The test results indicated an average effective field capacity of 0.172 ha/h at an average forward speed of 2.90 km/h. The field efficiency was 66.05 percent.

2.2 Precision Planters

Anonymous (2000) developed the world's first electronic seed metering system. A revolutionary device that accurately metered the seed, from the bulk hopper to multiple outlets. Noticeably more accurate over a wide range of seed types than virtually all of the existing equipment on the world market. Best suited to seeds ranging in size from 10 to 1000 seeds/gram. The unique patented rotating sponge pad gently separated and metered the seed without damaging it. Each metering head was supplied with three different shaped sponges to suit a wide range of shapes, sizes, and types of seed. A 12 V DC, geared motor driven by a sponge rotor within a vertical cylindrical metering hopper. The metering Plate bad multiple channels in its internal wall, along which seeds are gently separated by the rotating sponge and carried to individual outlets. The gentle nature of the sponge ensured that seeds were never damaged, and a wide range of seeds could be accurately metered. The speed of the drive motor was controlled electronically.

Gupta *et al.,* (1994) developed a manually operated electrostatic planter for small seeds. The electrostatic force was used for metering the small seeds. The machine consisted of pick-up pins of ebonite and a chain sprocket mechanism. The pick-up pins were fixed on the rotating wheel. Hill-to-hill spacing was adjusted by varying the 10 number of pick-up pins on the rotating wheel. To get the electrostatic charge the pick-up pins were rubbed against a piece of woollen cloth. This charge was enough to pick up 1 to 4 seeds at a time. The seeds were released by a metallic scrapper and passed through the seed tubes in the furrow. The planter was tested in the laboratory as well as in field conditions. The average slip of the ground wheel in laboratory conditions was about 11 per cent at an average velocity of 0.5 m/sec. The average draft for pushing the planter was 105 N.

Heege and Feldhauns (2002) presented a method, which included a compensating program for recording errors due to seeds clusters falling through the seeds. The control computer got the data from the light detector mounted below the seed tube. When the number of seeds passed through the detector deviated from the adjusted seed frequency, an electric worm gear was actuated and changed the transmission ratio for the seed metering. The control computer got the data from the light detector mounted below the seed delivery tube. The control- the computer was connected to a speed sensor in order to adopt the seed frequency needed to change travel speed.

Odigboh *et al.,* (1991) developed a two-row automatic planter. Planter was tested in the field and showed up a field capacity of 0.34 to 1.32 ha/h at a speed of 1.9 to 7.35 km/h with nearly 100 % efficiency. It was suggested that the planter should not be operated above 5.5 km/h to avoid brushing minisetts

Shearer and Holmes (1991) developed a precision-type metering mechanism with a submerged turbulent air jet directed at an artificial turf barrier. In this system, as the air jet passed through a seed mass, individual seeds were picked up and held against the barrier. The seed was dropped by cutting the air jet with a rotating disk.The prototype was evaluated in laboratory conditions. The results obtained were: (a) The seed metering accuracy was very sensitive to changes in speed and pressure. (b) Nozzle inside diameters of 1.2 and 1.6 mm worked best on soybean seeds. (c) Nozzle-to-seed clearance was needed to be best for the seeds of corn and soybeans. (d) Under average population and planting conditions, a power input of 1.6 kW was required per metering unit.

Ukthu (2003) made some modifications to the injection-type planter. The planter was redesigned in such a way that only a few parts come in contact with the soil. When tested on sandy and sandy loam soils, there was no soil attachment that would impair its functioning. The implement could plant maize, soybean, and cowpea seeds.

2.3 Performance evaluation of planters

Yazgi *et al.,* (2007) studied to optimize the seed spacing uniformity and performance of a precision seeder using response surface methodology (RSM) and to verify the optimum levels of the variables. The variables considered in the study consisted of the vacuum on the seed Plate, the diameter of seed holes and the peripheral speed of the seed Plate. Cotton seeds were used for sowing and experiments conducted in this study were based on the central composite design (CCD), one of the designs in RSM. Data obtained in the laboratory were divided into three different groups in order to obtain values of the multiple indexes, quality of feed index and mass index. An additional performance criterion was also proposed and used as an indicator of the sowing performance. This was the root-mean-square deviation from the theoretical seed spacing. The data obtained in the laboratory were then used to develop functions in a polynomial form that allowed the calculation of the optimum level of each independent variable considered in the study. The optimum levels of vacuum pressure and the diameter of holes for precision seeding of cotton seeds were found to be around 5.5 kPa and 3 mm, respectively. No optimum value was obtained for the peripheral speed of the seed Plate. It was found that the lower the peripheral speed of the Plate, the higher the performance.

Chungian (1989) developed a device to test the uniformity of seed falling. The device consists of a solid-state camera, a microprocessor, and interfacing circuits. The solid-state camera is composed of lenses of charge-coupled devices. Solid state image sensor was used to obtain the seed presentation which was processed by the computer. The device could measure seed spacing for the precision seeding of soybean and corn. The measuring error of seed spacing was less than 3 mm.

Karayel *et al.,* (2006) A high-speed camera system for evaluating seed spacing uniformity and velocity of fall of seeds described. The performance of the high-speed camera system in terms of seed spacing evaluation was compared with a sticky belt test stand, used as a reference. Identical seed patterns were evaluated by applying both methods simultaneously using wheat and soybean seeds. The speed of the metering rollers of the seed drill was set at 10, 20, 30 and 40 rpm and that of the seed drill at a simulated travelling speed of 1 m/s. In general, the high-speed camera system worked well in obtaining the seed spacing and velocity of the fall of seeds. In all the tests with the wheat and soybean seeds, the high-speed camera system did not miss any seeds. The sowing uniformity of the seed drill as investigated was affected by the speed of the metering rollers. The coefficient of variation of seed spacing, the velocity of fall and the coefficient of variation of velocity of fall of seeds decreased as the speed of the metering rollers increased.

Garcia *et al.,* (1997) studied a computer-based seeding rate controller, using the sensor for detecting the seeds dropped from the hopper and the traveling speed, and a personal computer to control the seed metering mechanism using pulse width modulation. The rotational speed of the metering mechanism, driven by a 12 V DC motor, was established, and ranged from 7 to 87 rpm using 6 different pulse frequencies and 9 duty ratios ranging from 20 to 100%. The seed metering calibration curve of the metering mechanism was also established under these speed ranges. Equations to calculate the “ON” and ‘Off’ periods to be used for the control program were developed.

Li *et al.,* (2003) discussed a new multi-seeder dynamic testing technology using image processing and analysis technique and a universal test bed to test the performance of precision seeder and grain drills. A dynamic test of a precision seeder at step-less speed was developed and then a new image processing and analysis technique used to examine the precision of the seeders and the accuracy of the procedure.

Anantachar *et al.,* (2009) made an attempt to develop the feed-forward artificial neural network (ANN) models for the prediction of the performance parameters of an inclined Plate seed metering device. The data were generated in the laboratory by conducting experiments on a sticky belt test stand provided with a seed metering device and an optoelectronic seed counter. The generated data was used to develop both statistical and neural network models. The performance of the developed models was compared among themselves for 4 randomly generated test cases. The results show that the ANN model predicted the performance parameters of the seed metering device better than the statistical models. In order to determine the optimum forward speed of the planting equipment, the peripheral speed of the metering Plate and the area of cells on the Plate to obtain the recommended seed rate of 33.33 seeds/m2, seed spacing of 100 mm and per cent seed damage of 0.2 % with 100 % fill of the cells, a novel technique of reverse mapping using ANN model was followed. It was observed that the optimum forward speed of the planting equipment and the optimum area of cells on the metering Plate had a good correlation with the size of the seed. Linear regression equations were developed to predict the optimum forward speed of the planting equipment and the optimum area of cells on the metering Plate using the size of seeds as an independent parameter. The peripheral speed of the metering Plate 14 of 0.237 m/s was found to be optimum for the size of seeds in the range of 95.42 to 123.01 mm2. However, the results need to be verified by conducting planting operations under actual field conditions.

Singh *et al.,* (2005) investigated the performance of the seed-metering device of a pneumatic planter under laboratory and field conditions to optimize the design and operating parameters for cotton seed planting. The effect of the operational speed of the disc, vacuum pressure and shape of the entry of the seed hole was evaluated by examining the mean seed spacing, precision in spacing (coefficient of variation), miss index, multiple indexes, and highest quality of feed index. For picking single seeds, the planter disc had a seed hole of 2.5 mm in diameter. The entry cone angle of the hole was varied from 90 to 150˚, the speed varied from 0.29 to 0.69 m/s, and the vacuum pressure from 1 to 2.5 kPa. The metering system of the planter was set to place the seeds at 250 mm spacing. It was observed that the planter disc with a 120˚ entry cone angle gave a superior performance at all speeds and operating pressures.

CHAPTER III

MATERIAL AND METHODS

This chapter deals with the experimental setup and instruments used for conducting tests on sticky belt stand in the laboratory. The detailed account of development microcontroller-based seed metering mechanism for precision planting has been described in the following sections. The research work was conducted in Farm Machinery Testing and Training Centre, Department of Farm Power and Machinery, Dr. Panjabrao Deshmukh Krishi Vidyapeeth in 2022-23.

3.1 Research plan

To fulfil the objectives of the present study, the research plan was finalized based on the reviews. This included experimental set-up, procedure adopted, instrumentation, experimentation, data collection and analysis.

3.2 Experimental details

1. Physical characterization of soybean seeds.
2. Development of microcontroller-based seed metering mechanism.
3. Design of experiments
4. Experimental setup for testing of microcontroller-based seed metering mechanism
5. Testing of microcontroller-based seed metering mechanism

3.2.1. Physical characterization of soybean seeds.

The physical dimensions of soybean seeds were measured by selecting of 50 seeds randomly. Physical characterization of soybean seeds characterized the physical properties of soybean seed for selection of seed Plate for seed metering mechanism Mean length, mean width and mean thickness of seed was measured by vernier calliper accordingly, a seed Plate which accommodated one to two seeds of soybean in a cell was selected for the study. Similarly, a seed hopper was also selected from the market to accommodate 4 to 5 kg of seeds.

3.2.2 Development of microcontroller-based seed metering mechanism

The following agrotechnical requirements of planters were taken into consideration for development of microcontroller based seed metering mechanism for precision planting.

1. It opens the furrow at proper depth to sow the seeds.
2. It meters the seeds as per recommendation.
3. It maintains seed-to-seed and row-to-row spacing.
4. It simulates the seed and places it at the proper depth.
5. It compacts the soil to the proper degree of compaction around the seeds.

3.2.2.1 Drive mechanism

The selected seed Plate of soybean seed was vertically mounted on the shaft of hopper. A shaft of 12V DC motor is directly coupled to the shaft of seed Plate metering shaft with the help of chuck drill. The motor was powered by 12V battery.

3.2.2.2 Working of seed metering unit

The metering unit consists of the seed cell Plate casing, the shaft to rotate the metering Plate, the 12 V DC motor, and the seed outlet pipe. The seed cell Plate casing, made up of high-density plastic was fitted to the hopper by means of nuts and bolts. A chuck drill was fitted to the casing and the metering Plate was fitted to it by means of a lock nut. The other end of the chuck drill was connected to the shaft of the DC motor, which gave drive to the metering Plate. The components and complete seed metering unit eliminated chain and sprocket assembly of ground wheel and seed metering unit shown in Plates 3.1 and 3.2

a) Chuck drill connected with shaft of seed plate **b) Chuck drill**

Plate 3.1 Component of seed metering unit

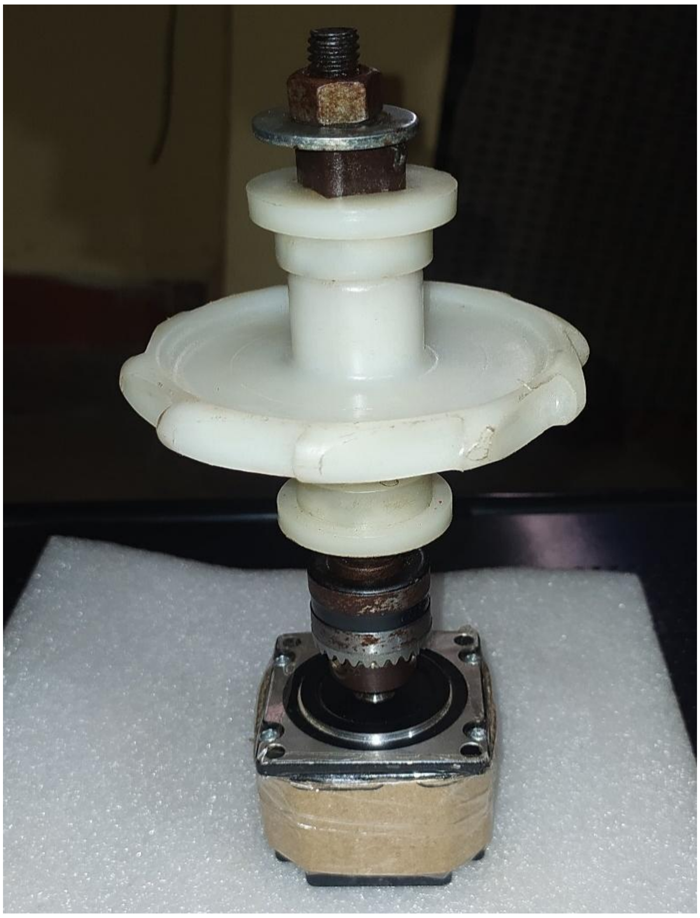

Plate 3.2 Seed metering Plate coupled with DC motor

3.2.2.3 Hopper and metering plate

The hopper was selected from the market made up of fibre of 3 mm thickness and the seed planter hopper described here offers a compact yet spacious storage area for seeds, with dimensions of 22.5 cm x 19.5 cm x 17.5 cm. The hopper was supported by a frame measuring 31 cm x 7 cm, providing stability and structural integrity. It features a circular opening with a diameter of 4 cm and a hopper opening measuring 6 cm x 7 cm for efficient seed distribution. The hopper's capacity was determined to be 6 x 22.5 x 19.5 cm^3, and its trapezoidal shape ensures optimal seed distribution during the seeding process. The views of hopper were shown in Plate 3.3

a) Side view

b) Side view

c) Top view

Plate 3.3 Views of hopper used for the study

On the basis of physical dimensions of soybean, seed metering Plate was selected with 10 cells on the Plate. The diameter of the metering Plate was 90 mm and the dimensions of cell 6 mm length, 6 mm breath, and 6 mm in thickness.

a)

b)

c)

Plate 3.4 Metering plate and fitted to hopper

3.2.2.4 Proximity sensor

A proximity sensor is a sensor able to detect the presence of nearby objects without any physical contact. A proximity sensor often emits an electromagnetic field or a beam of electromagnetic radiation (infrared, for instance), and looks for changes in the field or return signal. The object being sensed is often referred to as the proximity sensor's target. Different proximity sensor targets demand different sensors. For example, a capacitive or photoelectric sensor might be suitable for a plastic target an inductive proximity sensor always requires a metal target. The maximum distance that this sensor can detect is defined "nominal range". Some sensors have adjustments of the nominal range or mean to report a graduated detection distance. Proximity sensors can have high reliability and long functional life because of the absence of mechanical parts and lack of physical contact between the sensor and the sensed object. For the metering mechanism an inductive type proximity sensor was used as the target was used a metal strip and the nominal range of the proximity sensor was 8 mm. The proximity sensor was fitted on the frame maintaining an 8 mm gap between the ground wheel and itself. The proximity sensor senses the rpm of the ground wheel and transmits the impulse to the microcontroller. The microcontroller was so programmed that it reduces the rpm of the seed Plate with decrease in ground wheel speed and vice versa. A setup of a proximity sensor with ground wheel of planter is shown in Plate 3.5

Plate 3.5 Setup of a proximity sensor with the ground wheel

3.2.2.5 Arduino uno microcontroller

The Arduino uno is a low-power, high-performance CMOS 8-bit microcomputer with 4K bytes of flash programmable and erasable read-only memory (PEROM). The device was manufactured using high-density non-volatile memory technology and was compatible with the industry-standard MCS-51 instruction set and pinout. The on-chip flash allows the program memory to be reprogrammed in-system or by a conventional non-volatile memory programmer. By combining a versatile 8-bit CPU with flash on a monolithic chip, the Arduino Uno is a powerful microcomputer that provides a highly-flexible and cost-effective solution to many embedded control applications. The microcontroller programming for L298N motor driver was written and given below. The Arduino uno board, labelled diagram of Arduino uno circuit diagram of electronic components of seed metering unit are shown in Plate 3.6, Fig 3.1, and Fig 3.2, respectively.

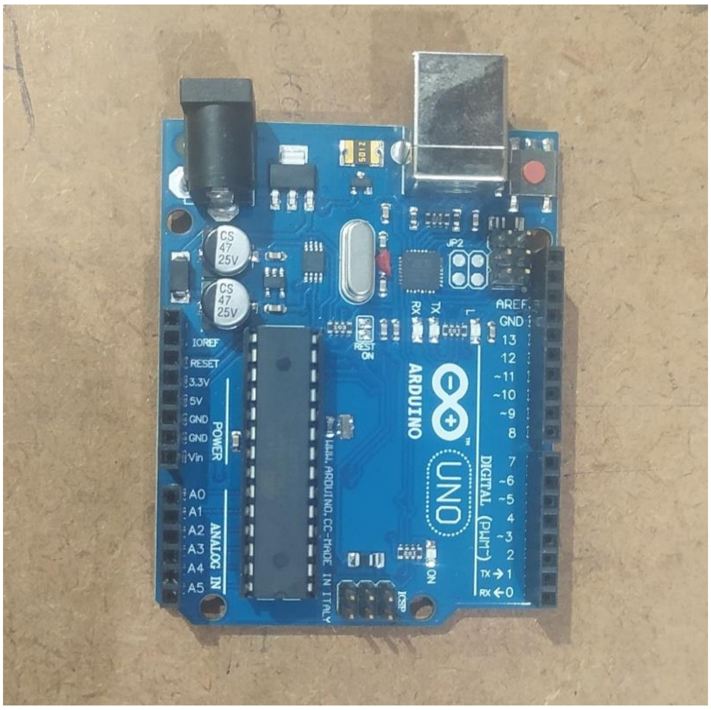

Plate 3.6 Arduino uno board

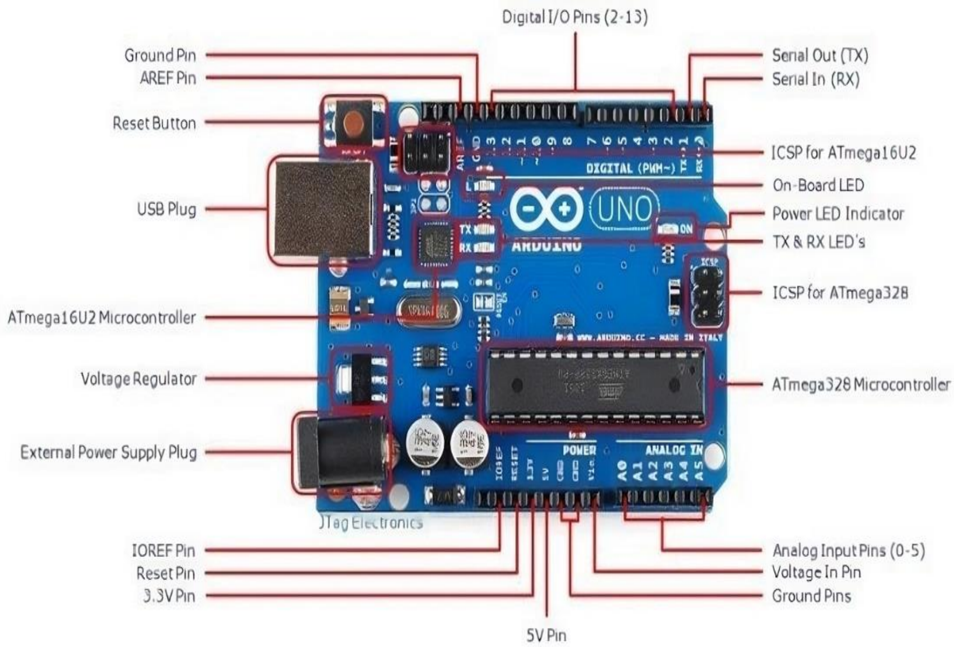

Fig. 3.1 Labelled diagram of Arduino uno

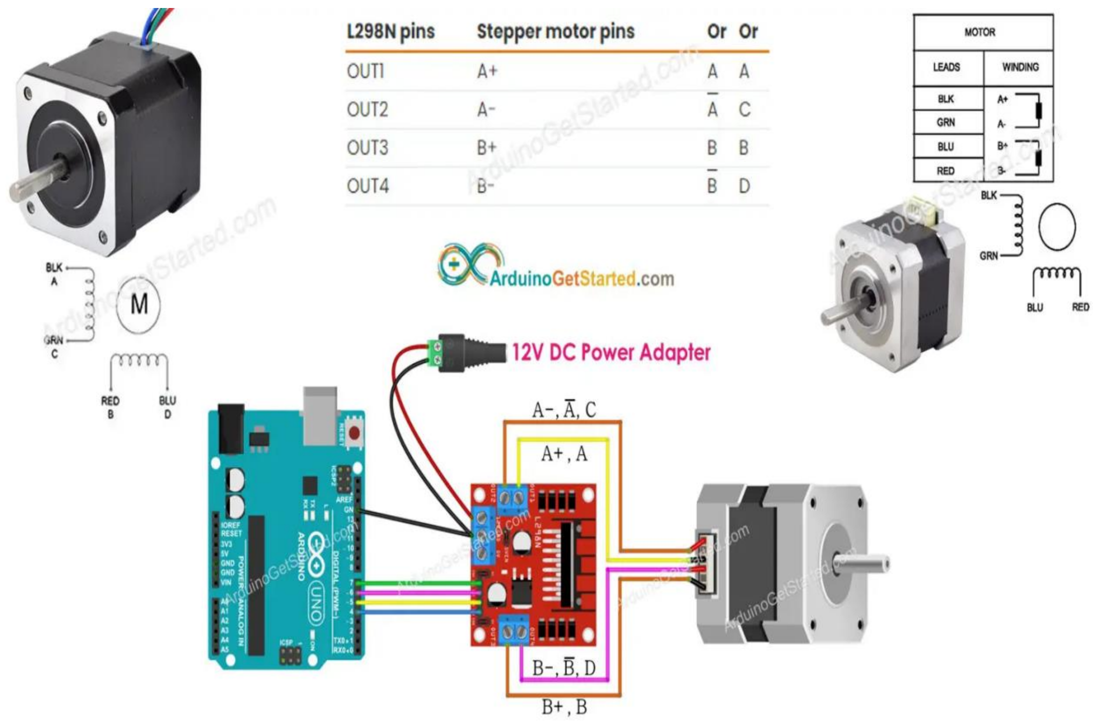

Fig. 3.2 Circuit diagram of electronic components of seed metering mechanism

The program was written in C++ computer language for operation of microcontroller based seed metering mechanism and is given below.

```
//Include the Arduino Stepper Library
#include <Stepper.h>
long int r;
volatile int state = 0;
long int time;
long int oldval = 0;
int inPin = 1; // pin3arduino
// Number of steps per output rotation
const int stepsPerRevolution = 100;

// Create Instance of Stepper library
Stepper myStepper(stepsPerRevolution, 4, 5, 6, 7);
void setup()
{

 pinMode(inPin, INPUT_PULLUP);
 attachInterrupt(inPin, func, FALLING);
 Serial.begin(9600);
 // initialize the serial port:

}

void loop()
{
   if (state > 0)
 {
   time = millis();
   r = ((60000/(time - oldval)*state)) ;
```

```
    oldval = time;
    state = 0;
    Serial.print("RPM = ");
    Serial.println(r);
    myStepper.setSpeed(r);
    myStepper.step(stepsPerRevolution);
    // set the speed at 60 rpm:

  // step one revolution in one direction:
//Serial.println("clockwise");

  //delay(500);

  }

  //delay(500);// step one revolution in the other direction:
  //Serial.println("counterclockwise");
  //myStepper.step(-stepsPerRevolution);
  //delay(500);
}
void func()
{
  state++;
}
```

The microcontroller was programmed in such a way that the motor stops rotating when the sensor stops receiving signal and the rpm increases with an increase in the rpm of the ground wheel of the tractor. The rpm of the ground wheel was sensed by the proximity sensor.

3.2.2.6 L298N motor driver

The L298N is a quadruple half-H-bridge motor driver. It was designed to provide 600 mA current at voltages from 4.5V up to 36V. It was possible to drive DC motor in both directions with it, using only 2 pins per motor. Motor drivers act as current amplifiers since they take a low-current control signal and provide a higher-current signal. This higher current signal was used to drive the motors. The detailed pin diagram of L298N motor driver along with labels are shown in Plate 3.7 and Fig. 3.3

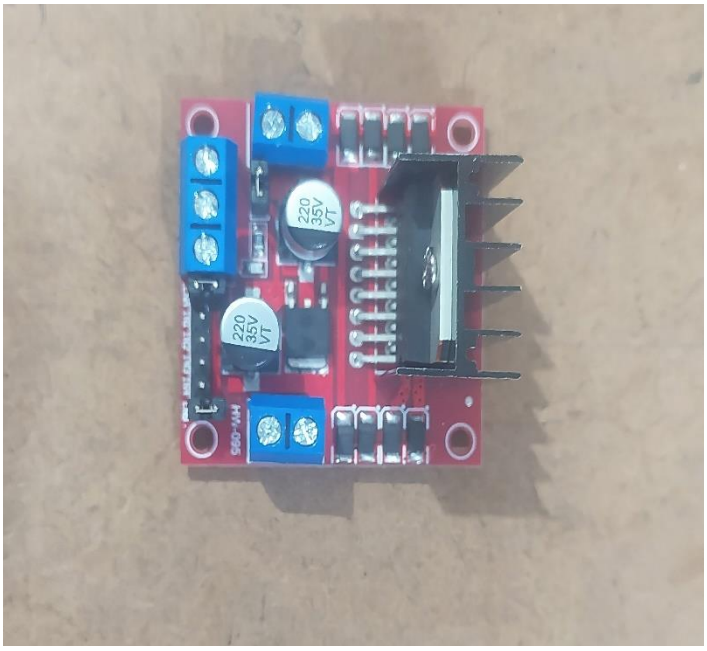

Plate 3.7 L298N motor driver

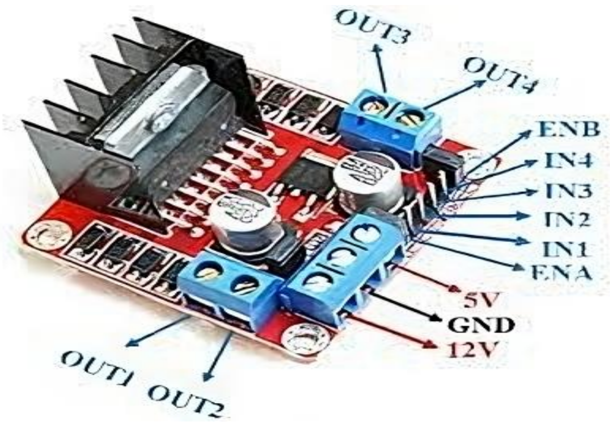

Fig. 3.3 Labelled diagram of L298N motor driver

3.2.2.7 TB6600 motor driver

TB6600 Arduino is an easy-to-use professional stepper motor driver, which could control a two-phase stepping motor. It is compatible with Arduino and other microcontrollers that can output a 5V digital pulse signal. TB6600 Arduino stepper motor driver has a wide range of power inputs and a 9~42VDC power supply. And it is able to output a 4 amp peak current, which is enough for most stepper motors. The stepper driver supports speed and direction control. micro step and output current with a 6 DIP switch can be set. There are 7 kinds of micro steps (1, 2/A, 2/B, 4, 8, 16, 32) and 8 kinds of current control (0.5A, 1A, 1.5A, 2A, 2.5A, 2.8A, 3.0A, 3.5A) in all. And all signal terminals adopt high-speed optocoupler isolation, enhancing its anti-high-frequency interference ability. As a professional device, it is able to drive 57, 42-type two-phase, four-phase, hybrid stepper motors. the connection of motor driver with Arduino uno is shown in Plate 3.8. The circuit diagram of motor drive Arduino uno and stepper motor is shown in Fig. 3.4

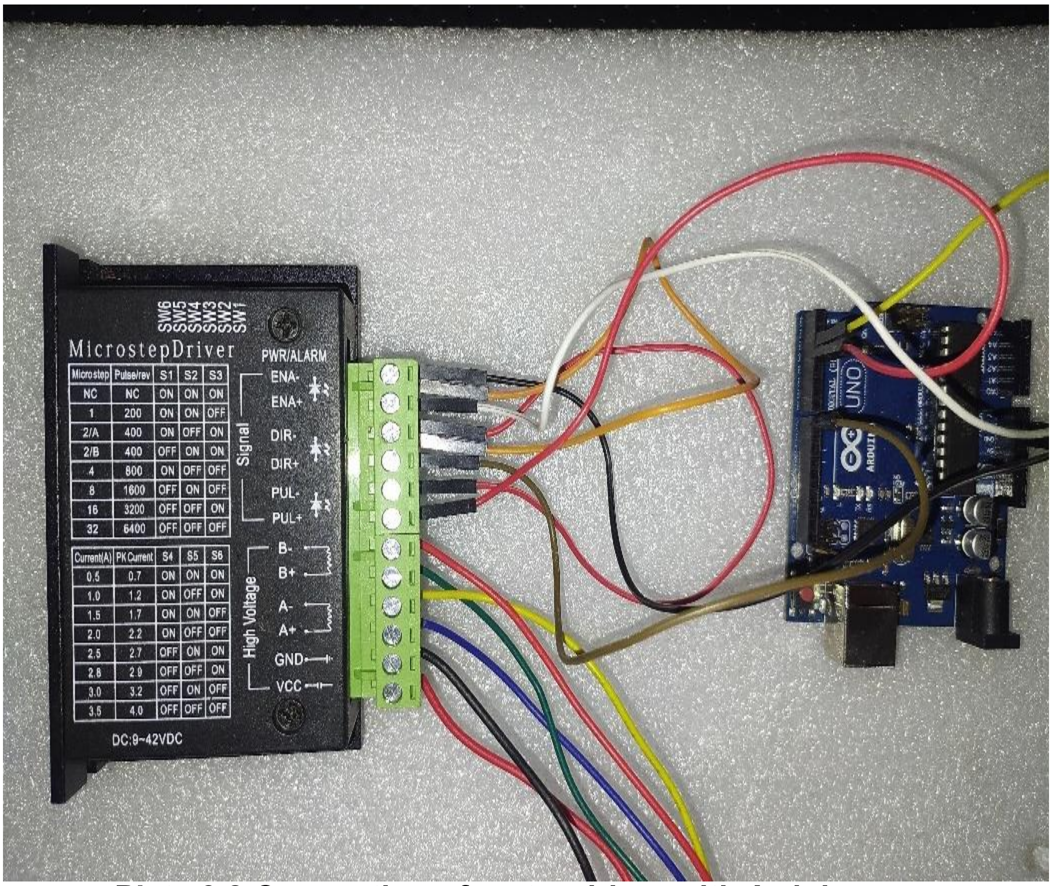

Plate 3.8 Connection of motor driver with Arduino uno

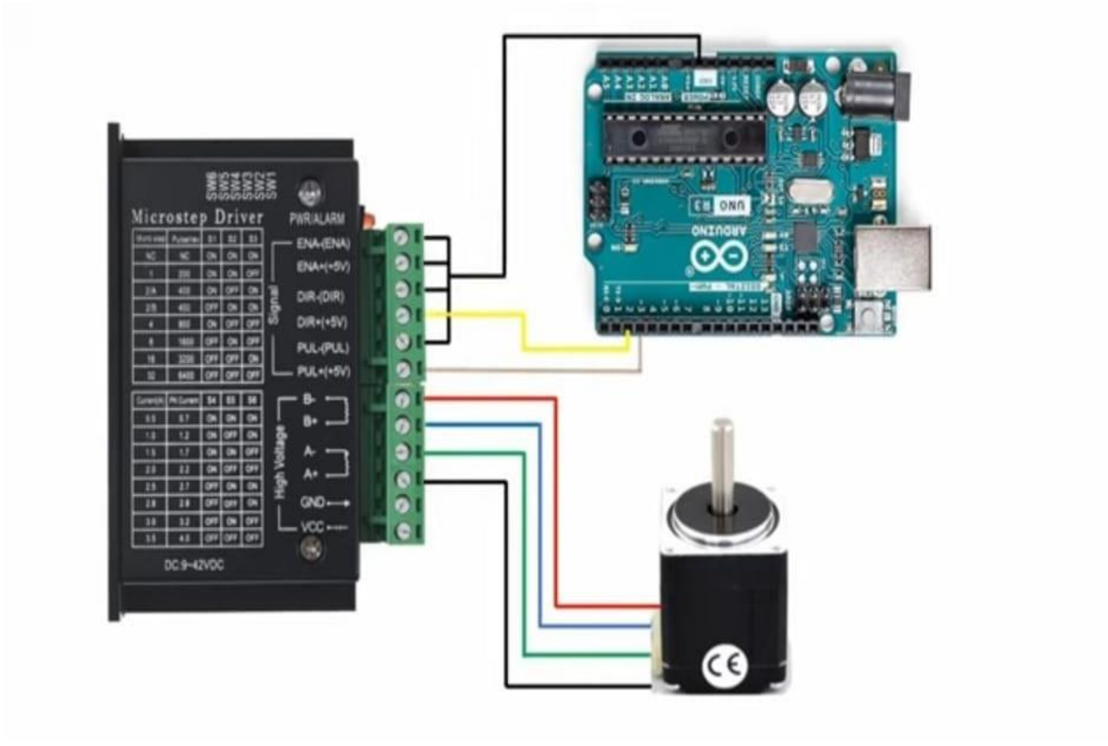

Fig. 3.4 Circuit diagram of motor driver, Arduino uno, and stepper motor

The program was written in C++ computer language for TB6600 motor driver and is given below.

Arduino Uno program of TB6600 motor driver (JSR_CODE_3)

```
#include <Stepper.h>



#define STEPS_PER_REVOLUTION 200 // Replace with the actual steps per revolution of your stepper motor

#define dirPin 8

#define stepPin 3

#define proximityPin 2 // Replace with the pin number connected to the proximity sensor



Stepper stepper(STEPS_PER_REVOLUTION, dirPin, stepPin);

bool previousStatus = LOW; // Variable to store the previous proximity sensor status
```

```
void setup() {
  pinMode(proximityPin, INPUT); // Set proximityPin as input
  digitalWrite(dirPin, HIGH); // Set the spinning direction CW/CCW
  Serial.begin(9600);

  // Delay after initializing the motor driver
  delay(600); // Adjust the delay time as needed

  stepper.setSpeed(400); // Set the speed of the stepper motor (in steps per second)
}

void loop() {
  int proximityStatus = digitalRead(proximityPin);
 // Debounce the proximity sensor
  delay(5);  // Adjust the delay time as needed
  proximityStatus = digitalRead(proximityPin);
  if (proximityStatus == HIGH && previousStatus == LOW) {
    stepper.step(STEPS_PER_REVOLUTION); // Move the stepper motor one full revolution
    delay(5); // Delay to allow the motor to complete the revolution (adjust as needed)
  }
   previousStatus = proximityStatus; // Store the current status for comparison in the next iteration
}
```

3.2.2.8 Overall working of microcontroller-based seed metering mechanism

A microcontroller based seed metering unit was developed by the use of a vertical Plate seed metering mechanism. The vertical Plate was revolved by the use of a variable speed, high torque DC motor. We eliminate the chain sprocket transmission system of the planter used for operating seed metering mechanism. The proximity sensor senses the RPM of the ground wheel and transmits the impulse to the microcontroller. The microcontroller was programmed so that it converts the pulses of the ground wheel to our desired revolution of the stepper motor that revolves the seed metering mechanism with the help of the motor driver and gives efficient seed-to-seed spacing. The flow chart of working of microcontroller based seed metering mechanism is given below in Fig. 3.5

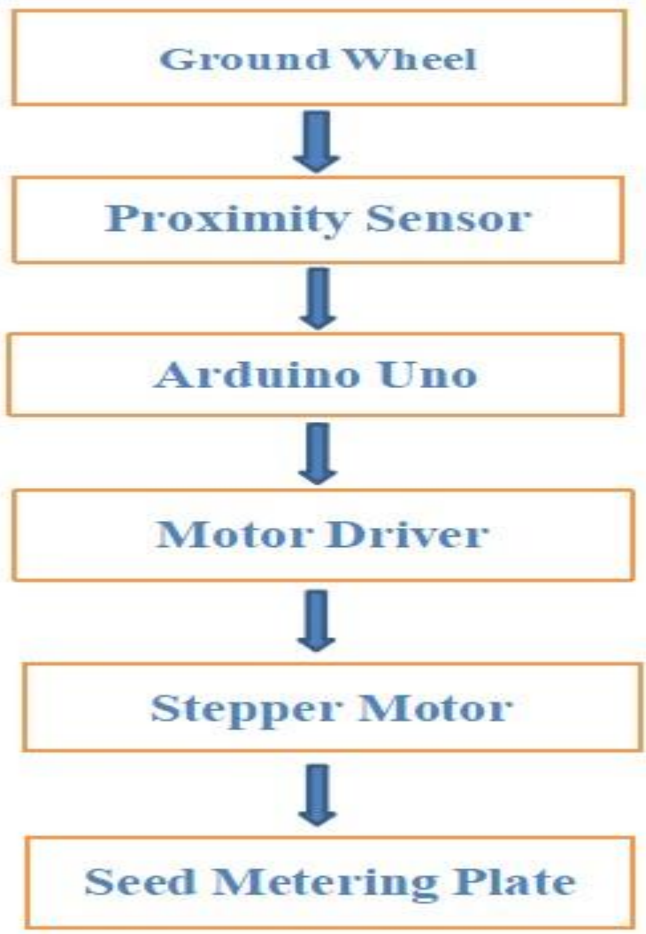

Fig. 3.5 Flow chart of working of microcontroller based seed metering mechanism

3.2.3 Design of experiment

The following independent and dependent variables were considered for testing of the microcontroller based metering mechanism in laboratory. The details of parameter studied are given in table 3.1

Table 3.1 Parameters of study

Sr.No.	Independent variable	Levels	Dependent variable
1	Forward speed km/h	3,3.5 and 4.5	1. seed to seed spacing, cm 2. miss index , % 3. multiple index, %

3.2.4 Experimental setup for testing of microcontroller based seed metering mechanism

The experiment was conducted in the Farm Machinery Testing & Training Centre, Department of Farm Machinery and Power Engineering, College of Agricultural Engineering and Technology, Dr. PDKV, Akola. A conveyor belt of 4000 mm was taken for preparing the grease belt. It was mounted on two rollers separated by 5000 mm. The rollers were driven by a 1hp variable speed DC motor. The hopper was mounted on one end of the conveyor belt and the tests were carried out. The speed of the conveyor belt was controlled by a speed regulator. The complete laboratory setup was shown in Plate 3.9. The experiments were carried out using soybean seeds. At first, the seeds were properly graded in a sieve shaker and were used for testing in the experiment. The conveyor belt speed was set as per desired levels of experiments. A speed level of 3 km/h, 3.5 km/h and 4.5 km/h were set for conducting seeding uniformity test of soybean seed. The facility for conducting seeding uniformity test by sticky belt method was used to ensure the uniformity in metering. The average forward speed of planter machinery was considered for the study i.e., 3.5 km/h and on the lower level and higher level of forward speed were also study to find the effect of lower and higher forward speed. The rpm of the hopper motor was controlled by the 9 to 42 V stepper motor supply by varying the voltage. The seeds were filled in the hopper and operated for a time period; the seeds obtained counted at three levels of forward speeds. The seed-to-seed spacing was observed by the spacing of seeds on the grease belt. The seeding uniformity test for soybean seed was conducted on sticky belt having 5 m long to travel under the seed tube in such a way that speed of the belt is equal to running speed of planter. Applied a sticky layer of grease on the belt to facilate proper enbendding of seeds without any displacement. Operated the metering mechanism from ground wheel on the sticky belt unit and observed the number of seeds dropped for each meter of belt length.

Plate 3.9 Sticky belt test setup for testing seed metering mechanism

3.2.5 Testing of microcontroller-based seed metering mechanism

The microcontroller-based seed metering mechanism was tested in laboratory for determination of seed uniformity, miss index, and multiple index.

3.2.5.1 Seeding uniformity

Operate the seed metering unit on sticky belt method also varying forward speed viz; 3, 3.5 and 4.5 km/h and measured the seed to seed spacing by foot rule. The seeding uniformity is shown in Plate 3.10

Plate 3.10 Seeding uniformity on sticky belt

3.2.5.2 Determination of miss index

The concept of the miss index was used to evaluate the performance of a planter or seed distribution system. It helps to determine the percentage of missed seed drops or failures in achieving the desired seed-to-seed spacing during planting operations. After conducting a sticky belt test on the planter, several parameters were measured and observed. These parameters include the number of seed drops, the seed-to-seed spacing, and the pattern of seed drops. Using this collected data, the miss index was calculated to assess the performance of the planter. The miss index represents the percentage of missed seed drops or failures to achieve the desired seed spacing. It indicates the effectiveness and accuracy of the planter in achieving the desired planting density. Miss index is the total number of observations with spacing more than 1.5 times theoretical spacing. The miss index is determined by the following equation.

$$\mathbf{M\ I = \frac{\boldsymbol{\varepsilon}}{\boldsymbol{N}} \ X\ 100}$$

Where,

M I – miss index, %

$\boldsymbol{\varepsilon}$ - The total number of observations with spacing more than 1.5 times the theoretical spacing

N - Total number of observations.

3.2.5.3 Determination of multiple index

Multiple index is the total number of spacings, which are less than 0.5 times the theoretical spacing. The multiple index is determined by following equation.

$$MI = \frac{\psi}{N} \times 100$$

Where,

MI - Multiple Index %

ψ - Total number of observations with spacing, which are less than 0.5 times of theoretical spacing

N - Total numbers of observations

3.2.5.4 Filler trails of seed metering unit in soil

A single unit of microcontroller based seed metering mechanism was fitted on the existing frame of planter and is shown in Plate 3.11

Plate 3.11 Existing seed planter with microcontroller seed metering unit

CHAPTER IV

RESULTS AND DISCUSSION

The results obtained from the investigation on development of microcontroller based metering mechanism for precision planting have been presented and discussed. The results and discussions consist of determination of physical property of soybean seed, seed uniformity, miss index, and multiple index on sticky belt unit.

4.1 Physical parameters of soybean seeds.

The physical dimension of soybean seeds of variety Swarna were determined. Selected 50 soybean seeds randomly and measured and mean value of length, breath, and thickness of seeds and are given in Table 4.1 and calculations are given in [Appendix I].

Table 4.1 Physical parameters of soybean seeds

Sr. No.	Particular	Mean value
1	Length of seed, mm	6.93
2	Breath of seed, mm	5.82
3	Thickness of seed, mm	4.78

4.2 Laboratory testing of microcontroller based seed metering mechanism.

The microcontroller-based seed metering mechanism was tested in laboratory on sticky belt method and determined seed uniformity, miss index, and multiple index.

4.2.1 Seeding uniformity

Seeding uniformity of seed metering mechanism was chucked on sticky belt method for soybean seed. The seed to seed spacing was observed to be

10.31, 8.89, and 9.43 cm at 3, 3.5, and 4.5 km/h forward speed of ground wheel operated by DC motor against the theoretical seed to seed spacing of 9.2 cm (Fig. 4.1).

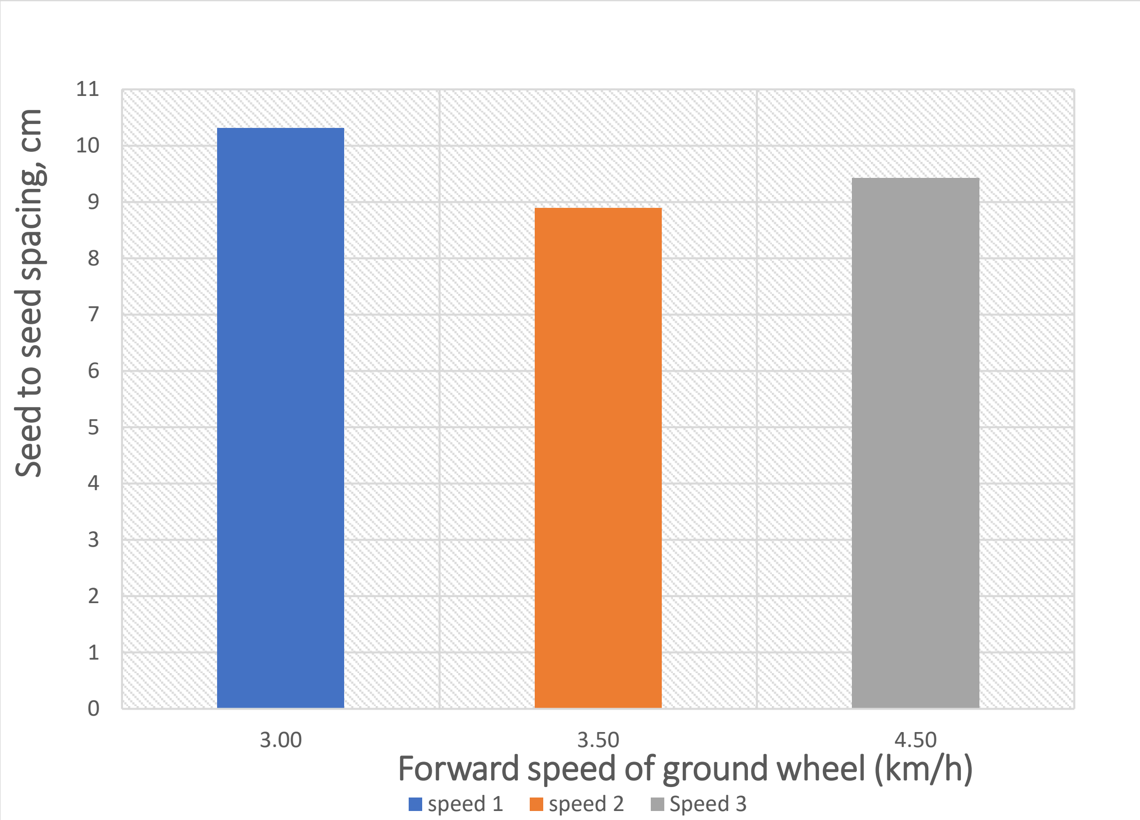

Fig 4.1 Seeding uniformity of seed metering mechanism

4.3 Miss index of seed metering mechanism

The miss index was determined by using the same setup of sticky belt method. The miss index were found to be 21.05, 20.0, and 21.21 % at 3.0, 3.5, and 4.5 km/h forward speed of ground wheel. Minimum miss index was observed to be 20% at 3.5 km/h forward speed with increased of forward speed (Table 4.2). The calculations of determination of miss index given are in [Appendix II].

Table 4.2 Miss index of seed metering mechanism

Sr. No.	Forward speed of ground wheel, km/h	Total number of observations, Nos.	Theoretical seed to seed spacing, cm	Total number of observations with spacing more than 1.5 times theoretical spacing, Nos.	Miss index (%)
1	3.0	38	9.2	8	21.05
2	3.5	35	9.2	7	20.00
3	4.5	33	9.2	7	21.21

4.4 Multiple index of seed metering mechanism

The multiple index using microcontroller based seed metering mechanism was determined on sticky belt method it was found to be 13.11, 20.0, and 18.18 % at 3.0, 3.5, and 4.5 km/h forward speed of ground wheel. Minimum value of multiple index was found to 13.11% (Table 4.3)

Table 4.3 Multiple index of seed metering mechanism

Sr. No.	Forward speed of ground wheel, km/h	Total number of observations, Nos.	Theoretical seed to seed spacing, cm	Total number of observations with spacing which are less than 0.5 times theoretical spacing, Nos.	Multiple index (%)
1	3.0	38	9.2	5	13.11
2	3.5	35	9.2	7	20.00
3	4.5	33	9.2	6	18.18

CHAPTER V
SUMMARY AND CONCLUSIONS

Agriculture is the backbone of the Indian economy. Though India is self-sufficient in food grain production the rate of increase of per capita availability of food has been alarmingly low. The decreasing rate is due to the fact of not using a high-yielding variety of seeds and the implementation of improper sowing techniques. Uniform seed spacing is one of the most important factors in crop production. It affects crop growth and yield. Planters are extensively used in now a day's farming for maintaining proper seed-to-seed spacing and depth of sowing. It is generally believed that automatic and electronic control increases the efficiency, compactness, and durability of the machine. Considering these factors, the development of an electronic metering mechanism for the precision planting of seeds was undertaken with the objectives, of development of microcontroller-based seed metering mechanism for precision planting and evaluation of performance of the developed microcontroller based seed metering mechanism in laboratory

The metering unit consists of the seed cell Plate casing, the shaft to rotate the metering Plate, the 12 V DC motor, and the seed outlet pipe. The seed cell Plate casing, made up of high-density plastic was fitted to the hopper by means of nuts and bolts. A chuck drill was fitted to the casing and the metering Plate was fitted to it by means of a lock nut. The other end of the chuck drill was connected to the shaft of the DC motor, which gave drive to the metering Plate. The components and complete seed metering unit viz; chain and sprocket assembly of ground wheel and seed metering unit were eliminated.

The physical parameters of the seeds were measured for selection of proper seed Plate. The proximity sensor was fitted on the frame maintaining 8 mm gap between the ground wheel. The proximity sensor sensed the rpm of the ground wheel and transmit the impulse to the Arduino uno microcontroller, and the microcontroller was so programmed to reduce the rpm of seed Plate.

The experiment was conducted in the Farm Machinery Testing & Training Centre, Department of Farm Machinery and Power Engineering, College of Agricultural Engineering and Technology, Dr. PDKV, Akola. The microcontroller-based seed metering mechanism was tested in laboratory on sticky belt method and determined seed uniformity, miss index, and multiple index.

The analysis of seeding uniformity demonstrated reasonably consistent seed spacing, although slight variations were observed at different forward speeds. The developed mechanism achieved seed-to-seed spacing within the range of 10.31 cm to 9.43 cm, compared to the theoretical spacing of 9.2 cm. This indicates that the seed metering mechanism effectively controlled seed placement.

The evaluation of the miss index, representing observations with spacing greater than 1.5 times the theoretical spacing, revealed values ranging from 20% to 21.21% across forward speeds of 3.0, 3.5, and 4.5 km/h. The lowest miss index of 20% was achieved at a forward speed of 3.5 km/h, indicating improved accuracy at this speed. Furthermore, the multiple index analysis, which considered observations with spacing less than 0.5 times the theoretical spacing, yielded values ranging from 13.11% to 20% across forward speeds of 3.0, 3.5, and 4.5 km/h The lowest multiple index value of 13.11% was obtained at a forward speed of 3.0 km/h.

The microcontroller-based seed metering mechanism showcased promising performance in terms of seed uniformity, offering potential for precision planting of soybean seeds. The mechanism achieved consistent seed spacing and effective seed placement within acceptable ranges. Further optimization and field testing are recommended to validate the system's performance under real-world conditions.

CHAPTER VI
SUGGESTION FOR FUTURE WORK

The development of the microcontroller-based single-row seed metering mechanism marks a significant advancement in agricultural technology. However, to further enhance its performance and capabilities, several suggestions for future research work are proposed.

1. The complete microcontroller-based seed metering mechanism may be developed for multiple rows.

2. Inclined Plate metering mechanism may be used for better performance of seed metering mechanism.

3. planter may be developed using micro controller-based seed metering mechanism and endurance test may be conducted.

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CHAPTER VII

BIBLIOGRAPHY

Arzu.Y, Adnan.N, Degirmencioglu. (2007). Optimisation of the seed spacing uniformity performance of a vacuum-type precision seeder using response surface methodology, Biosystems Engineering 97, 347 – 356.

Aware.V.V. (2008) Development of proximity distance sensor based electronic metering mechanism for three rows planter 2008 Agriculture Update, Vol. 3 No. 3&4: 296-299 (Aug. & Nov. 2008).

Benneweis, R.K., Bloom. (1993). Communication system for an air seeder monitor. Trans. of ASAE, 93(4), 13-16

Chungian. (1989). Testing the uniformity of seeds, American Society of agricultural engineers 15(1): 23-25 Data Book for Agricultural Machinery Design, CIAE, Bhopal.

Garcia, Kito and Wang.X.L. (1997). Computer based optimal control of seeding rate based on travel speed and seed signals. Journal of Japanese Society of Agricultural Machinery. 59(6) 93-101

Gupta, (1994). A manually operated electrostatic planter. Agricultural engineering 45(5) :554-555.

Heege and Feldhans. (2002) Program for recording errors due to seed clusters through a tube. American Society of agricultural engineers 29(1): 35-39

Karayel.D, Wiesehoff.M, Ozmerzi.A, Muller.J (2006). Laboratory measurement of seed drill seed spacing and velocity of fall of seeds using high-speed camera system. Computers and Electronics in Agriculture 50 89–96.

Karthikeyan.K. 2004. Developed an electronic seed monitoring system for planters. Unpublished M. Tech thesis, Department of Agricultural food engg. IIT Kgp.

Lan, et al. (1999). Opto electric sensor system for laboratory measurement of seed spacing. J. Agricultural Engineering Res:72: 119-127.

Li Wei, Lin Jia-chun, Zhan Bin, Tan Yu-zhi. (2003). A dynamic test of seeder performance based on imaging techniques, Paper number 033092, 2003 ASAE Annual Meeting

Minjin.A, (2003). Dibble precision seeder for coated rice seeds. Agri Mechanisation in Asia, Africa, and Latin America. 34(4): 9-17.

Odigboh.E, (1991). A two-row automatic miniset yam planter. J. Agric Engg. 50: 189-196.

Shearer, S.A., and Holmes. (1991). Precision seed metering mechanism with a turbulent jet. American society of agricultural engineering. 34(3): 781-786.

Singh.R.C, Singh.G, Saraswat D.C. (2005). Optimization of Design and Operational Parameters of a Pneumatic Seed Metering Device for Planting Cottonseeds, Biosystems Engineering 92 (4), 429–438.

Ukthu. (2003) Modification of injection planter for the tropics. Agri Mechanisation in Asia, Africa, and Latin America. 34(4): 20-23.

APPENDIX I

A) Physical dimensions of soybean seeds

Sr. No.	Length	Breadth	Thickness
1	6.54	6.01	4.30
2	7.39	5.99	5.15
3	8.06	5.80	4.83
4	7.14	5.71	4.97
5	7.11	6.18	4.86
6	6.87	6.00	4.87
7	7.23	5.99	4.66
8	6.88	6.18	5.02
9	7.03	5.87	4.87
10	7.55	6.28	5.30
11	7.25	5.98	4.66
12	7.33	6.56	5.17
13	7.16	6.11	5.08
14	6.46	5.45	4.61
15	6.27	5.50	4.34
16	6.52	4.82	4.47
17	7.32	6.03	5.31
18	7.07	5.09	4.65
19	6.60	5.76	4.87
20	7.20	6.57	4.96
21	6.38	5.75	4.84
22	6.20	5.22	4.44
23	6.40	5.81	4.89
24	6.93	5.60	4.09
25	6.98	5.31	4.57
26	7.55	6.28	5.15
27	7.03	5.87	4.97
28	6.88	6.18	4.87
29	7.23	5.99	5.02
30	6.87	6.00	5.30
31	7.11	6.18	5.17
32	7.14	5.71	5.08
33	8.06	5.80	4.34
34	7.39	5.99	5.31
35	6.54	6.01	4.87
36	7.25	5.98	4.84
37	7.33	6.56	4.89

38	7.16	6.11	4.57
39	6.46	5.45	4.30
40	6.27	5.50	4.83
41	6.52	5.31	4.86
42	7.32	5.60	4.66
43	7.07	5.81	4.80
44	6.60	5.22	4.53
45	7.20	5.75	4.61
46	6.38	6.57	4.47
47	6.20	5.76	4.65
48	6.40	5.09	4.96
49	6.93	6.03	4.44
50	6.98	4.82	4.89
Avg.	6.93	5.82	4.78

APPENDIX II

A) Calculation of theoretical seed-to-seed spacing

Diameter of ground wheel, D – 44 cm

Number of revolution of the ground wheel, Ng – 1

Number of revolution of vertical Plate, Np – 1.5

Number of cells in Plate, n – 10

Seed to seed spacing = $\frac{\pi D N g}{Np\ X\ n}$

$$= 3.14 x 44 x \frac{1}{1.5\ x\ 10} = 9.2 \text{ cm}$$

B) Determination of miss Index and multiple Index

1) Forward speed of ground wheel 3 km/h

Observation No.	Seed-to-seed spacing on the sticky belt (cm)
1	10
2	18
3	9.5
4	3
5	12
6	10
7	11
8	2
9	8
10	6
11	5
12	11
13	18
14	3
15	20
16	1.5
17	8
18	7
19	9
20	5

21	5
22	3
23	20
24	11
25	9
26	7
27	2
28	8
29	16
30	5
31	17.5
32	6
33	9
34	18.5
35	7
36	19
37	9
38	6
Average value	10.31

A) Determination of miss Index at 3 km/h forward speed

M I = $\frac{\varepsilon}{N}$ X 100

Where,

$\boldsymbol{\varepsilon}$ = the total number of observations with spacing more than 1.5 times the theoretical spacing

N = Total number of observations.

Theoretical seed to seed spacing = 9.2 cm

In the above observation,

$\boldsymbol{\varepsilon} = 8$

N = 38

M I = $\frac{\mathbf{8}}{\mathbf{38}}$ **X 100 = 21.05%**

B) Determination of multiple Index at 3 km/h forward speed

$$MI=\frac{\psi}{N} X\ 100$$

Where,

MI =Multiple Index %

ψ = Total number of observations with spacing, which are less than 0.5 times of theoretical spacing

N = total no of observation

ψ = 5

N = 38

$$\mathbf{MI=\frac{5}{38}\ X\ 100\ \ =\ \ 13.11\%}$$

2) Forward speed of ground wheel 3.5 km/h

Observation No.	**Seed to seed spacing on the sticky belt (cm)**
1	8
2	9
3	12.8
4	3
5	2
6	14
7	17
8	9
9	6
10	8
11	5
12	12.5
13	2.5
3	3
15	14
16	2

17	18
18	9
19	7
20	6.5
21	7
22	19
23	9
24	2
25	21
26	5
27	5.5
28	3.5
29	22
30	7
31	9
32	13
33	7
34	3
35	10
Average value	8.89

A) Determination of miss Index at 3.5 km/h forward speed

$$\text{Ms I} = \frac{\varepsilon}{N} \times 100$$

Where,

$\boldsymbol{\varepsilon}$ = the total number of observations with spacing more than 1.5 times the theoretical spacing

N = Total number of observations.

Theoretical Seed to Seed spacing = 9.2 cm

In the above observation,

$\boldsymbol{\varepsilon} = 7$

N = 35

Ms I = $\frac{7}{35}$ X 100 = 20%

B) Determination of multiple Index at 3.5 km/h forward speed

$$MI=\frac{\psi}{N} X\ 100$$

Where,

MI =Multiple Index %

ψ = Total number of observations with spacing, which are less than 0.5 times of theoretical spacing

N = total no of observation

ψ = 7

N = 35

$$\mathbf{MI=\frac{7}{35}\ X\ 100\ =\ 20\%}$$

3) Forward speed of ground wheel 4.5 km/h

Observation No.	Seed to seed spacing on the sticky belt (cm)
1	8
2	9
3	5
4	2
5	14
6	2.5
7	7
8	12.5
9	8
10	3
11	7
12	14
13	13
14	3
15	15.5

16	11
17	2.5
18	10
19	16.5
20	1.5
21	9
22	9
23	17
24	8
25	19
26	6
27	8
28	22
29	6.5
30	13
31	9
32	12.5
33	7.5
Average	9.43

A) Determination of miss Index at 4.5 km/h forward speed

Ms I = $\frac{\varepsilon}{N}$ X 100

Where,

$\boldsymbol{\varepsilon}$ = the total number of observations with spacing more than 1.5 times the theoretical spacing

N = Total number of observations.

Theoretical Seed to Seed spacing = 9.2 cm

In the above observation,

$\boldsymbol{\varepsilon}$ = 7

N = 33

Ms I = $\frac{7}{33}$ X 100 = 21.21%

B) Determination of multiple Index at 4.5 km/h forward speed

$$MI = \frac{\psi}{N} \times 100$$

Where,

MI =Multiple Index %

ψ = Total number of observations with spacing, which are less than 0.5 times of theoretical spacing

N = total no of observation

ψ = 6

N = 33

$$\mathbf{MI = \frac{6}{33} \times 100 = 18.18\%}$$