Fabrication and performance evaluation of a seed-cum-fertilizer broadcasting machine

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Abstract: A seed cum fertilizer broadcasting machine was fabricated and the performance study of the machine was done in the field. The machine is portable and can be moved easily by hanging at the backside of a man and is operated by a rechargeable battery of 12 volt. The machine is built with a steel frame with a hopper in which seeds or fertilizers can be inserted and an opening hole with a metering device proceeds seeds or fertilizers to drop on the beater arm platform. Then a beater arm swings the falling seeds or fertilizers and throws them towards the field. After development, the machine's performance study was conducted in the lab and the field. In the laboratory performance, the average uniformity coefficient of distribution (UCD) for urea, green gram, wheat, and black gram was found to be 94.7%, 91.7%, 94.12% and 95.38%, respectively. To assess the actual field performance of the machine, planting was done with black gram seeds both manually and mechanically. The field was divided into 4 plots. Manual broadcasting was done in two plots of the field and mechanical broadcasting was done in another two plots of the field. The average value of the coefficient of variation (CV) for mechanical and manual broadcasting was found 13.99% and 65.26%, respectively from the field. The amount of variation was much higher in manual broadcasting. This higher variation indicates that there was less uniformity in the field where manual broadcasting was done. In conclusion, the machine is aesthetically good for farmers to use for broadcasting purposes.

Keywords: Seed, Fertilizer, Broadcasting machine, Development, Performance study.

Citation: Sarker, M. K. U., M. A. Munnaf, M. Fahmida, M. F. A. Tapu, M. Islam, S. Foisal, M. A. Muktadir, and D. Das. 2025. Fabrication and performance evaluation of a seed-cum-fertilizer broadcasting machine. Agricultural Engineering International: CIGR Journal, 27(3):102-111.

1 Introduction

Agriculture is a predominant sector in Bangladesh in generating livelihood, employment, and GDP contribution. A large number of people directly or indirectly engage in agricultural work. Among all crops wheat, mustard, til, cheena, barley, and kaon, all pulse and many vegetable crops are cultivated by hand broadcasting method. (BBS, 2022) The area cultivated for those crops and their production was 0.183 ha, 0.172 M. Tons for barley 439232.85 ha, 777718 M. Tons, for wheat, 499.79 ha, 1034 M. Tons for oilseeds and 30068.14 ha, 424000 M. Tons for pulses. Broadcasting is the process of random scattering or spreading seeds on the surface of

Received date: 2024-09-13 **Accepted date:** 2024-11-01

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seedbeds that may or may not be incorporated into the soil or covered with soil or similar other materials. Broadcasting of seeds can be done manually (by hand) and mechanically (mechanical spreader or airplane). Sowing small seeds is operated manually by small-scale farmers which normally results in poor distribution of the planted seeds (Awulu, et al., 2014). When the seed is broadcasted manually, it cannot be distributed uniformly all over the field and it is very time-consuming. It was estimated that undesirable effects of non-uniform broadcasting would economically lose a large amount of money (Svensson, 1990). The row-to-row spacing, seed rate, and seed-to-seed spacing vary from crop to crop and for different agricultural and climatic conditions to achieve optimum yields. An efficient sowing machine should attempt to fulfill these requirements (Marode, et al., 2013).

In hand broadcasting, farmers take a container in one hand, and another hand is used to spread seed, which is very uneasy for a farmer. That's why farmers cannot broadcast seeds more than 4-5 hrs. nonstop. Continuous broadcasting with a hand for a long time may cause muscle irritation, knee pain, foot pain, back pain, and so on. During the period of seeding, the labor crisis is common for manual broadcasting due to industrialization, the garments industry, and urbanization. Due to excess wages and limited workers, the peak period of crop planting is exceeding in many areas in the country. Timely sowing is an important agronomic practice that ensures normal seed germination, stable seedling establishment, and final yield formation. Delay in the sowing of wheat results in reduced crop yield of 30-40 $kg.ha^{-1}.day^{-1}$ if wheat is sown after 13th November (Baranwall, 1995; Hobbs, 1988). This loss can be saved through early and fast seeding of seeds using a broadcasting machine instead of a hand broadcasting method. On the other hand, in hand operating seed broadcaster, farmers had to rotate handles that connect with a horizontal arm which helps to broadcast seed. The non-uniform speed of the handle and horizontal arm causes the non-uniform distribution of seed. However, the goal is to distribute seeds uniformly. For this reason, uniform rotation is necessary for uniform broadcasting. A battery-operated motor can rotate the seed broadcasting beater blade uniformly.

Seed spreading of the spreader by electrical and mechanical means could be more uniform and achieve high field capacity and efficiency compared to the traditional broadcasting method (Tajuddin, 1989). For this reason, an attempt was made to design, develop, and evaluate the performance of a battery-operated seed cum fertilized broadcasting machine. The outcomes of the proposed research can play an important role in the improvement of the socioeconomic status of farmers and product processors.2 Materials and methods

A seed cum fertilized broadcasting machine was developed in the laboratory of the Agricultural and Industrial Engineering Department, Faculty of Engineering, Hajee Mohammad Danesh Science and Technology University, Dinajpur, Bangladesh from January to April 2022. It is located 413 km (25°37′N 88°39′E / 25.617°N 88.650°E) north-west of Dhaka Bangladesh. The machine was developed using Bangladeshi available materials and fabricated in the Bangladeshi workshop in Dinajpur. A sketch diagram of the seed cum fertilized broadcasting machine is shown in Figure 1.

Figure 1 Fabricated seed cum fertilizer broadcasting machine

It is a rechargeable battery-operated broadcasting machine. The basic components of the machine include a hopper, a seed regulator, a beater arm, a fiber platform, an agitator, a small motor (12V), a rechargeable battery (12 V), a cushion, and a belt to carry the machine at the back, a transformer and some additional electronic components to observe the available charge of the battery.

2.1.1 Hopper

The hopper is a 306 mm diameter cone-shaped device to hold the grain or fertilizer and is made of a steel plain sheet of 1 mm thickness having a capacity of 6486 cm^3. Different views of the hopper are shown in Figure 2.

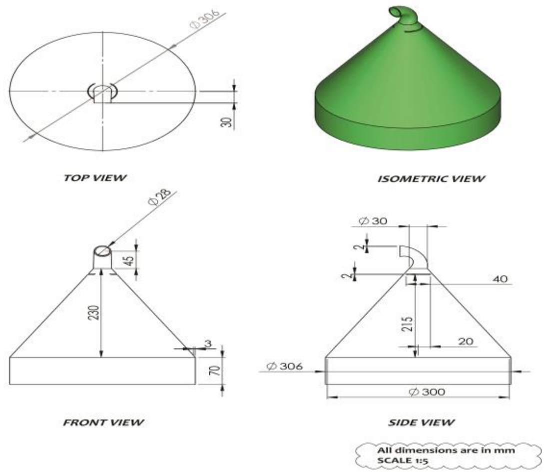

Figure 2 Hopper

2.1.2 Beater arm

The beater arm is made of steel with a length of 33cm. It is used to spread seed and fertilizer uniformly in the field. It was placed on the fiber platform and rotated using a motor (12V).

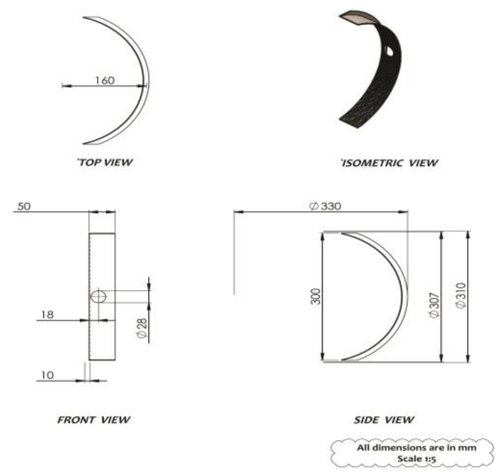

Figure 3 Beater arm

2.1.3 Design of the beater arm

The length of the beater arm was 37 cm and it was designed using the principle of circular motion and plane curvilinear motion of particles. The circular motion of a beater arm and the curvilinear motion of a particle is presented in Figure 4. The vertical and horizontal distance traveled by a particle P due to the beating action of the beater (Ziauddin and Poritosh, 1998). The velocity of a point on the beater is as follow:

$$V = \omega r = 2\pi r N \quad (1)$$

Where,

V = velocity, m sec^{-1},

ω = angular velocity, rad min^{-1},

N = rotor, rpm,

r = length of heater arm, m.

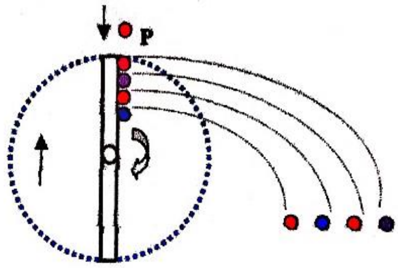

Figure 4 Circular motion of a beater arm and curvilinear motion

The fertilizer or seed as hit by the rotor arm at point p, travels through path AB (as in Figure 5) and obtains final velocity V before it drops on the ground. (Ziauddin and Roy, 1998) The horizontal distance (X) traveled by the particle could be found in the equations of the plane of curvilinear motion of particles, which as

$$X = Vt = V\sqrt{\frac{2h}{g}} \quad (2)$$

Where,

h = height of the beater arm from the ground during operation, m.

g = gravitation constant, m sec^{-2},

X = horizontal distance of distributed particles, m.

From Equation (3) (Ziauddin and Roy, 1998), Equation (4) can be gotten.

$$X = \frac{2\pi N r}{60}\sqrt{\frac{2h}{g}} \quad (3)$$

$$r = \frac{60X}{2\pi N}\sqrt{\frac{g}{2h}} \quad (4)$$

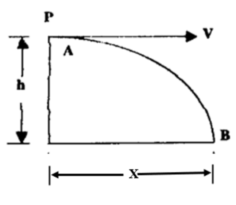

Figure 5 Plane curvilinear motion of a particle

2.1.4 DC motor

A 12V DC motor was used to rotate the rotor of the beater arm.

2.1.5 Seed metering device

The seed metering device was located at the bottom of the hopper. The seed metering device was designed in such a way that half-circular plates were used as metering devices. One side of the half-circular plate was fixed and the other side could be moved attached with a bolt and pinion. When the moveable plate moves closer the opening of the metering device becomes smaller. Thus, the movement of the different sizes of seeds could be controlled. This is named a gate-type metering device. Figure 6 shows the different views of the seed metering device.

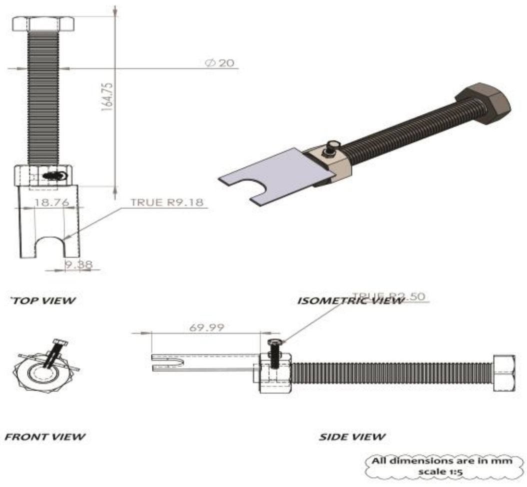

Figure 6 Seed metering device

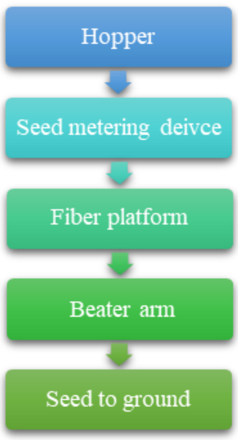

Figure 7 Operation diagram of the broadcaster

2.1.6 Agitator

An agitator was used for the prevention of clogging of seeds inside the hopper. A conical-shaped agitator was fixed with a shaft that was supported by a horizontal shaft fixed with the hopper. This agitator was rotated using a motor and rechargeable battery. The agitator helped smooth the movement of the grain seeds toward the seed regulator and avoided clogging of the seeds in the hopper.

2.1.7 Flow diagram of the machine operation

Figure 7 shows the operation flow diagram of material falling from the hopper to the ground.

2.1.8 Charging unit

Two 6V × 600 mA transformers were used in the charging unit of seed-cum fertilizer broadcasting machine. There is an AC cord which is used to connect the machine to the power supply for charging.

2.1.9 Switch box and battery

4 switches were installed in the switch box. The first one was used for charging. The second one was used for emergency backup if any switch did not work during fieldwork. The third one was used for the agitator motor on/off. Lastly, the fourth switch was used for a motor which was attached to the beater arm. This switch has two functions. This switch can combine the voltage of two batteries or run with the voltage of one battery. There were some indicator lights for each switch also. 12V Lead Acid battery was used in the machine.

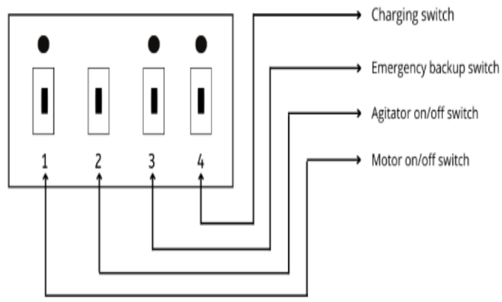

Figure 8 Schematic design of switch box

2.1.10 Cushion and belt

A cushion was used at the rear part of the machine which was attached to the steel frame by bolts. The cushion was divided into two parts. This division was done to pass the free air and also lose the weight of the machine. The cushions were made of a combination of foam, artificial leather, and fiberboard. Fiberboard was thin but durable and it could be incurved along with a human's back. Foam gave a comfortable feeling and artificial leather combined both foam and fiberboard also gave smoothness in the back. A belt was used for hanging the machine in the back.

2.1.11 Battery capacity meter and voltmeter

Batteries weren't always easy to work with and sometimes needed tools to be able to measure the remaining capacity and the voltage output to properly maintain good battery health for longevity. This was why tools like this 12V Lead Acid Battery Capacity and Voltage Meter, which was both a capacity measurement tool as well as a voltmeter, built into one elegant little package. It could identify precise charging and discharge rates for included batteries while finding the precise capacity to know how much energy still has to be spare to power the machine. The onboard battery indicators were quite simple, but offer a good level of information that could let us identify battery conditions at a glance. For capacity, the display offers 8 bars that depict the charge level remaining. This ranges from a single bar depicting that the battery voltage is above 11.1V, up to the full 8 bars, which depicts that the battery voltage is above 13.3V – enabling very quick identification of precise voltage levels remaining. A simple voltmeter is also included in it to evaluate a power source or quickly check the remaining voltages on battery cell packs.

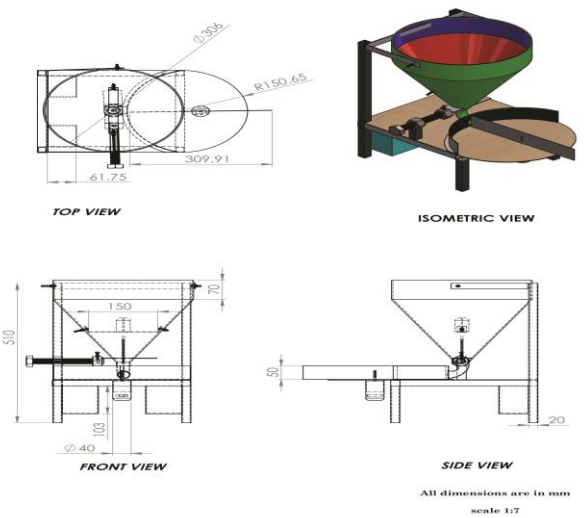

Figure 9 Fabricated seed cum fertilizer broadcasting machine

2.1.12 Fabrication of the seed cum fertilizer broadcasting machine

All the above-mentioned parts including the hopper, beater arm, fiber platform, seed metering device, agitator, charging unit, switch box, and battery were compiled together to fabricate the machine as shown in Figure 9. Different views of the machine are shown in the same figure. After fabrication, the machine was ready for laboratory and field tests.

2.2 Experimental details

2.2.1 Uniformity coefficient of distribution (UCD) test procedure

The selected area was 8 ×3.6 m and some foam plates with height 2.54 cm were placed randomly. It is located 413 km (25°37′N 88°39′E / 25.617°N 88.650°E) north-west of Dhaka Bangladesh. Foam plates were also useful against the bouncing effect of spreading seeds/fertilizers. An area of 15.24 m×2.62 m was selected and measured the forward speed of the machine was from covering the distance to time. Some plates were arranged in that area. The horizontal distance of plate to plate was 0.792 m and the vertical distance of plate to plate was 0.305 m.

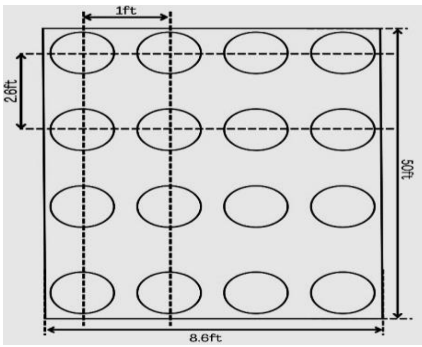

Figure 10 Schematic design of arranging plates

Then the machine was started from a specific point and allowed the seed/fertilizer to broadcast within the area. Urea, wheat, black gram, and green gram were used for broadcasting. The time required to cover the whole area was counted. After that, the seeds/fertilizers deposited in each plate were collected carefully and weighed in the weighing machine. To compare the results of uniformity coefficient of distribution (UCD) between manual broadcasting and mechanical broadcasting, an experienced farmer was hired to spread urea manually. Farmers spread urea in the cultivable land. The experiment was conducted from 02/05/2022 to 05/05/2022.

2.2.2 UCD test

The UCD is the key parameter to determine the uniformity of the distributor. The UCD was determined by using the following formula (Ziauddin and Roy, 1998).

$$UCD = 1 - \frac{\sum (Xi - \bar{x})}{n\bar{x}} \tag{5}$$

Where,

$\bar{x}$ = average weight of materials of each box,

x_i = weight of materials in each box,

n = number of plates taken for the test.

2.2.3 Calibration of the machine

The calibration of the broadcasting machine deals with the mechanism of how the seed rate is to be maintained. The optimum seed rate is the prerequisite for optimum plant density and thus maximum yield. According to the availability of seeds in the market, black gram seeds were selected for the field experiment. The seed rate for black gram was 35-40 kg ha^{-1}. So, the seed rate should be controlled by the opening of the metering device. The seed drill was calibrated for the seed rate in gm min^{-1} with different size openings by twisting the seed metering device. The seed rates were measured at 50%, 65%, 75% and 100% openings. Then a seed rate calibration curve was developed to determine the optimum seed rate for black gram seeds in gm min^{-1} . From the graph, 88% opening of the metering device was appropriate for broadcasting black gram seed with a discharge rate of 215.27gm min^{-1}. For the field experiment, the land size of 4 decimals was selected from the HSTU experimental field.

2.2.4 Land preparation

Firstly, brushwood, dirt, and weeds were removed from the field. After that, the land was tilled by a power tiller from the HSTU central farm. This was done properly to pulverize the soil and soften the earth. Finally, the land was leveled by the power tiller drawn leveler which was attached at the back of the power tiller. The land was divided into 4 equal plots having an area of 1 decimal each. The length was 15.24 m and the width was 2.65 m of each plot as shown in Figure 10. Every plot was divided from each other by ridge. The width of the ridge was 1 meter each.

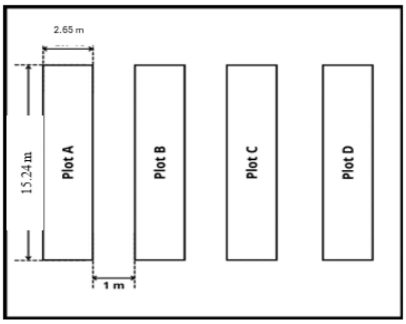

Figure 11 Schematic design of plotting the land

2.2.5 Seed broadcasting method

According to the standard specification, the black gram seed required for 1 decimal land was calculated to be 146 gm. The machine broadcasted 146 gm seeds in 41 seconds at 88% opening of the metering device for 1 decimal land. To do these, working practices were done to cover the land of the plot in 41 seconds. There were 4 plots for seed broadcasting. These four plots were indicated as Plot-A, Plot-B, Plot-C, and Plot-D. Plot-A and Plot-C were broadcasted mechanically using the broadcasting machine and Plot-B, and Plot-D was broadcasted manually. The same amount of seeds was broadcasted in each plot either manual or mechanical. After the broadcasting of the seeds laddering operation was done to cover the seeds. After 3 days the seeds germinated and after 12 days of showing plants were perfect for data collection.

2.2.6 Determining the uniformity of broadcast

To determine the uniformity of the plants grown 12 blocks of size 0.305×0.305m were chosen randomly from each plot. Each block was leveled according to the name of the plots. After creating blocks in each plot, the number of seedlings within each block was counted carefully. Then, the uniformity of the plants in mechanical and manual broadcasting was compared.

2.2.7 Standard deviation calculation:

The standard deviation (*SD*) of the distribution of plants in different squares of the selected size was determined by using the formula.

$$SD = \sqrt{\frac{\sum (Xi - \bar{x})^2}{N}} \quad (6)$$

Where,

$\bar{x}$= the mean number of plants in all squares,

x_i= number of plants in each square,

N = total number of plants in squares.

2.2.8 Coefficient of variation calculation

The coefficient of variation (CV)of the number of plants in different square plots was calculated using the formula (Brown, 1998)

$$CV = \frac{SD}{\bar{x}} \quad (7)$$

Where,

SD = standard deviation,

$\bar{x}$ = mean value (mean value of the number of plants in different square plots)

2.3 Theoretical field capacity

The theoretical field capacity of a machine is the rate of field coverage that would be obtained if the machine performs its function 100% of the time at the rated forward speed and covers 100% of its rated width (Berger *et al.*, 1978). The theoretical field capacity was calculated by using the following equation,

$$TFC = \frac{Sw}{c} \quad (8)$$

where,

TFC = theoretical field capacity, (ha.hr^{-1}),

S=forward speed of travel, km.hr^{-1},

W=total width covered, m,

C=constant, 10.

Forward speed of machine, S was varied with the speed of operator. The speed of travel was determined using the following equation,

$$S = \frac{d}{t} \quad (9)$$

Where,

d=distance traveled, km,

t=time, hr.

2.4 Effective field capacity

The effective field capacity is the actual average rate of coverage by the machine, based upon the total field time required (Berger et al. 1978). The effective field capacity was calculated by using the following equation,

$$EFC = \frac{A}{T} \quad (10)$$

Where,

EFC = effective field capacity, (ha.hr^{-1}),

A = actual area covered, ha,

T = total time required, hr.

2.5 Field efficiency

The field efficiency is the ratio of effective field capacity to theoretical field capacity and expressed in percent (Berger et al., 1978). The field efficiency was calculated by using the following equation,

$$Efficiency = \frac{EFC}{TFC} \times 100 \quad (11)$$

where,

EFC = effective field capacity, (ha.hr^{-1}),

TFC = theoretical field capacity, (ha.hr^{-1}).

3 Result and discussion

This section presents the results obtained from the laboratory and field experiment conducted with the seed broadcasting machine. of the machine with urea, wheat, black gram, and green gram, and the determination of seed rate for selected land.

3.1 Performance study of the seed broadcasting machine

The machine's performance was tested in the laboratory and field. The results are given in Table 1.

Table 1 Performance of the seed broadcasting machine

Test	TFC (theoretical field capacity), ha.hr^{-1}	EFC (effective field capacity), ha.hr^{-1}	Field efficiency, %
Laboratory test	0.219	0.159	74.29
Field test	0.3375	0.244	72.29

In the laboratory and field test of the machine, the theoretical field capacity was 0.219 and 0.3375 ha.hr^{-1}, and effective field capacity was 0.159 and 0.244 ha.hr^{-1} and field efficiency was 74.29% and 72.29 % respectively.

3.2 Determination of optimum opening for black gram seeds:

To fix up the amount of grain or seed rate for individual items (Urea, wheat, black gram, green gram, etc.), the calibration curve was developed for the opening of the seed regulator and the amount of seed discharged. Figure 12 shows the calibration curve for the black gram seeds.

The graph shows, that for 50% opening of the seed regulator amount of seed discharge was 10.1 kg. ha^{-1}. Similarly, for 65%, 75%, 88%, and 100% opening of the seed regulator discharge rate was 13.2, 15.8, 36.3, and 109.6 kg. ha^{-1}. The seed rate of black gram was 35-40 kg. ha^{-1} at 88% opening. The calibration shows the seed rate was 36.3 kg. ha^{-1} which was appropriate for black gram broadcasting.

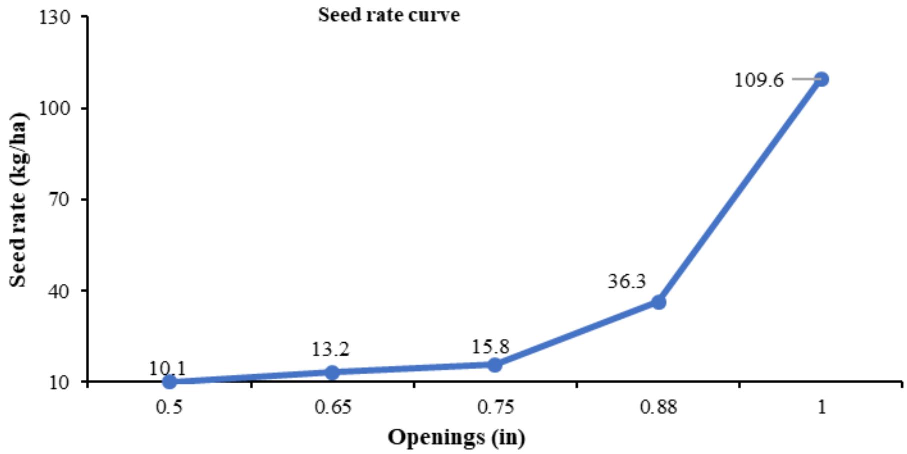

Figure 12 Seed rate line graph for Black gram seeds

3.3 UCD comparison

The result shows that the average UCD of mechanical broadcasting was (94.7%) higher than manual broadcasting (83.5%). So, the uniformity of distributing urea by seed cum fertilizer broadcasting machine in the field was much more uniform than hand broadcasting.

Table 2 UCD comparison between manual broadcasting and mechanical broadcasting using Urea

Experiment no.	UCD of manual broadcasting (%)	Average UCD of manual broadcasting (%)	UCD of mechanical broadcasting (%)	Average UCD of mechanical broadcasting (%)
1	83.63		95.69	
2	81.85	83.5	95	94.7
3	85		93.39	

Table 3 Determination of UCD by mechanical broadcasting for laboratory test

Serial No	Seed/Fertilizer name	Experiment no	Uniformity coefficient of distribution(UCD) %	Average UCD %
1	Urea	1	95.69	
		2	95	94.7
		3	93.39	
2	Green gram	1	92.15	
		2	91.62	91.7
		3	91.34	
3	Wheat	1	98.53	
		2	91.11	94.12
		3	92.73	
4	Black gram	1	95.89	
		2	93.54	95.38
		3	96.71	

3.4 Determination of UCD

The table shows the UCD determined for the urea, green gram, wheat, and black gram. 3 kinds of seeds and 1 kind of fertilizer were selected for laboratory experiments. The average UCD of urea, green gram, wheat, and black gram for all the cases was above 90%. The laboratory experiments were done on the concrete floor. There was a little bounce while the seed spreading. Bouncing had little effect on the spread pattern and uniformity (Parish, 1991). The results are quite satisfactory and for better results, performance should be done in large fields. For availability of seeds, black gram seed was selected for the field test.

Table 4 Coefficient of variation and standard deviation of mechanical broadcasting and manual broadcasting

Mechanical Broadcasting				Manual Broadcasting			
Block No. (plot A)	No. of plants (plants.929.03 cm^{-2})	Block No. (plot C)	No. of plants (plants.929.03 cm^{-2})	Block No. (plot B)	No. of plants (plants.929.03 cm^{-2})	Block No. (plot D)	No. of plants (plants.929.03 cm^{-2})
A-1	7	C-1	7	B-1	12	D-1	13
A-2	6	C-2	8	B-2	5	D-2	9
A-3	6	C-3	6	B-3	11	D-3	10
A-4	5	C-4	7	B-4	3	D-4	16
A-5	7	C-5	6	B-5	18	D-5	6
A-6	7	C-6	8	B-6	13	D-6	17
A-7	5	C-7	8	B-7	10	D-7	13
A-8	4	C-8	8	B-8	13	D-8	21
A-9	5	C-9	8	B-9	4	D-9	12
A-10	6	C-10	9	B-10	5	D-10	32
A-11	6	C-11	8	B-11	28	D-11	1
A-12	6	C-12	8	B-12	22	D-12	2
Total	70	Total	91	Total	144	Total	152
Mean $\bar{X}$	5.83	Mean $\bar{X}$	7.58	Mean $\bar{X}$	12	Mean $\bar{X}$	12.67
Standard deviation SD (%)	0.94	Standard deviation SD (%)	0.90	Standard deviation SD (%)	7.64	Standard deviation SD (%)	8.47
Coefficient of variation CV	16.12	Coefficient of variation CV	11.87	Coefficient of variation CV	63.67	Coefficient of variation CV	66.85

Table 5 Coefficient of variation comparison between mechanical broadcasting and manual broadcasting

Mechanical broadcasting			Manual broadcasting		
Plot name	Coefficient of variation, CV, %	Average CV, %	Plot name	Coefficient of variation, CV, %	Average CV, %
Plot-A	16.12	13.99	Plot-B	63.67	65.26
Plot-C	11.87		Plot-D	66.85	

3.5 Coefficient of variation comparison

Table 5 shows that the coefficient of variation of Plot-B and Plot-D was much higher than the coefficient of variation of Plot-A and Plot-C. So, the amount of variation in the number of seedlings was higher in manual broadcasting than in mechanical broadcasting in field tests. Finally, the result of mechanical broadcasting was impressive and efficient.

4 Conclusion

The performance of the machine was determined by laboratory tests and field tests. The result of the laboratory test was achieved by the UCD calculation method. The average results of the UCD test for urea, green gram, wheat, and black gram are 94.7%, 91.7%, 94.12%, and 95.38% respectively. The result was quite satisfactory. The field test result showed a 12.39% coefficient of variation for mechanical planting experimented with black gram, while the manual planting showed a 57.6% coefficient of variation. The result depicts that the machine broadcasting was far more uniform than manual. However, it is necessary to get the yield from field experimental results. The machine's performance is good as a manual broadcasting and is ready to use in the field.

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