Design and development of a drum seeder with urea supergranule application for rural farmers in Bangladesh

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Abstract: To overcome high human stress and drudgery in rice cultivation, a pull type manually operated drum seeder with urea supergranule application was designed and developed. It was tested in laboratory and farm for both super granular urea (GU) and paddy seeds. It has three drums for applying seeds and two hoppers for applying GU, which were placed over a shaft. A relationship was found between seed rate and filling condition of drum. The seed rate was 25.5 kg/ha when drum was full of seeds and it was 65 kg/ha when drum was fill up with one-fourth of its capacity. Metering device consisting four cups of 25.4 mm diameter and made of mild steel (MS) sheet was designed to apply the GU uniformly. Maximum missing percentage and over falling percentage for both the hoppers were found 3%. The average distance between applied GU to GU was found 0.40 m. The effective field capacity of the applicator for applying GU was found 0.14 ha/hr at a speed of 2.21 km/hr and field efficiency was found 78.4%. On the other hand, the field capacity of the applicator for applying paddy seeds was found 0.33 ha/hr and field efficiency was found 87%. The machine was very easy to pull because pulling force was only 108 N. The weight of the whole applicator was only 12 kg. So it is very easy to carry from one field to another field. It is also very easy to operate manually and rural farmers can easily handle it manually.

Keywords: Paddy seed, drum seeder, super granular urea, urea applicator, field capacity, field efficiency

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1 Introduction

Bangladesh is an agricultural country. Rice is the major staple food in our country. Chemical fertilizers are required for increasing crop production. Farmers depend on urea fertilizer to meet the nitrogen plant requirement. Urea can be classified as fine and super granular type. Most of the farmers of Bangladesh are applying fine urea in the rice field by broadcasting method. The fine urea reduces the effectiveness of fertilizer so that losses can attain 70%. The losses occur in following ways: i) some of the fertilizers convert into gaseous ammonia and mix with air, ii) part of urea (or its hydrolysis product) is dissolved with rain or irrigation water and runoff to surrounding canal and river from the applied field, and iii) a part of the ammoniacal nitrogen can go beyond the root zone of the rice plants (NAP, 2009), notably in soils with great permeability without pan layer. Nowadays farmers of Bangladesh are applying granular urea by deep placement. Deep placement or subsurface placement of urea ensures better distribution of ammoniacal nitrogen within the anaerobic layer of the soil (Savant and Stangel, 1990; Gaudin, 2012; Gaudin and Onofrio, 2015) and prevent any loss by surface drain-off. On the other hand the methods of rice seeding vary from region to region such as transplanting, broadcasting or direct seeding, drilling and dibbling. Most of the farmers in Bangladesh use transplanting method to establish the rice crop.

Due to long processes, huge labor and production cost in transplanting method, nowadays direct seeding by drum seeder are used in Bangladesh. Drum seeding can increase the rice production by 5%-10% (Alam et al.

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2006; Alam et al. 2007). Manual transplanting requires approximately 25% of the total labor requirement of rice production (Singh et al. 1983); mechanical paddy transplanters are not available in Bangladesh. Transplanting typically needs about 20 man-days/ha, whereas direct wet seeding requires about 1-2 man-days/ha (Salam et al. 1992). The human stress and drudgery involved in transplanting operation is also very high. On the other hand, the problems of fine urea can be minimized by applying granular urea (GU) at a depth of 70-100 mm in rice field and this will increase 20%-25% rice production. Uneven application of fertilizer can result in unequal plant growth and maturity and yields. Application of fertilizer using machine is important because it is possible to achieve uniformity of fertilizer in root zone of all plants (Bansal and Leeuwfstein, 1987). But there is a lack of suitable machine for applying GU in Bangladesh. Only a prototype has been built by Hoque et al (2013). So farmers apply it by hand. This is not only laborious but also time consuming. It takes 200-300 man-hr to apply urea in 1 ha of land. It also creates back pain, and diseases in legs and fingers of the person who is applying urea. It requires full attention to place a GU at accurate depth and distance by hand: the main difficulty is to repeat this operation during hours. So performance of fertilizer and yield of rice are not satisfactory. On the other hand, there is no single machine for the purposes of both seeding and urea supergranule application in the field of Bangladesh. Considering the above facts and studies, an attempt had been made to develop a manually operated drum seeder with joint urea (super) granule application. In the study developed locally made single machine can be used for both the purposes. The proposed machine for two purposes will create new aspect in farm mechanization of Bangladesh. As a result, farmers' purchasing costs, operating cost, time and labor will be saved (Nishiura and Wada, 2012). The health of farmers will be free from back pain and risk of disease in legs and hand on account of using the applicator. It is expected that developed "drum seeder with urea granule application" will be accepted by the farmers due to its low energy requirement, low cost, reduced urea requirement, easy to operate, and increased rice production.

2 Materials and methods

2.1 Design considerations

The following factors were considered to design drum seeder with urea supergranule application: i) the machine should be simple in construction and easy to adjustment, ii) the size of the GU, iii) the size of drum, iv) distance between applied GU to GU and row to row placement, v) the row spacing and seed rate should be adjustable, vi) it should be easy to repairable and maintainable, vii) the cost of machine must be within the capacity of rural small farmers and viii) it should be light in weight and easy to operate by a single person (man or women). The distance between applied GU to GU should be maintained 0.4 m for designing the applicator (IFDC, 2007). The diameter of ground wheel was determined by considering the spacing between GU and number of GU fallen per turn of wheel. The wheel diameter was 0.51 m and it was made of plastic materials. The wheels were fixed with a hollow MS shaft (35 mm × 35 mm) by nuts and bolts. As a result, the shaft and metering system were rotated with the rotation of wheels during operation. The following information was considered for determining number of cups in the metering device. Diameter [D] of wheel is considered as 0.51 m. Distance covered per turn of wheel, [πD] is as 1.6 m. Number of turn of wheel is equal to number of turn of metering device, and distance between GU to GU is considered as 0.4 m. Therefore, total number of cups in the metering device is to be [1.6 m/0.4 m] 4.

2.2 Design and development of different parts of the applicator

Metering device is the most important part for the applicator and it is made of M.S sheet. Four cups of 25.4 mm diameter is welded with a flat bar and attached to the shaft. A hopper is made of M.S sheet with 90 mm wide and 180 mm long. There is a rubber gate on the hopper. The hopper is supported by an angle bar with bearings in opposite sides. When the shaft is rotated due to rotation of wheels, the metering device with the cups is also rotated. The cup holds a GU and drops in the furrow tube. Figure1 shows the different views of hopper with the metering device.

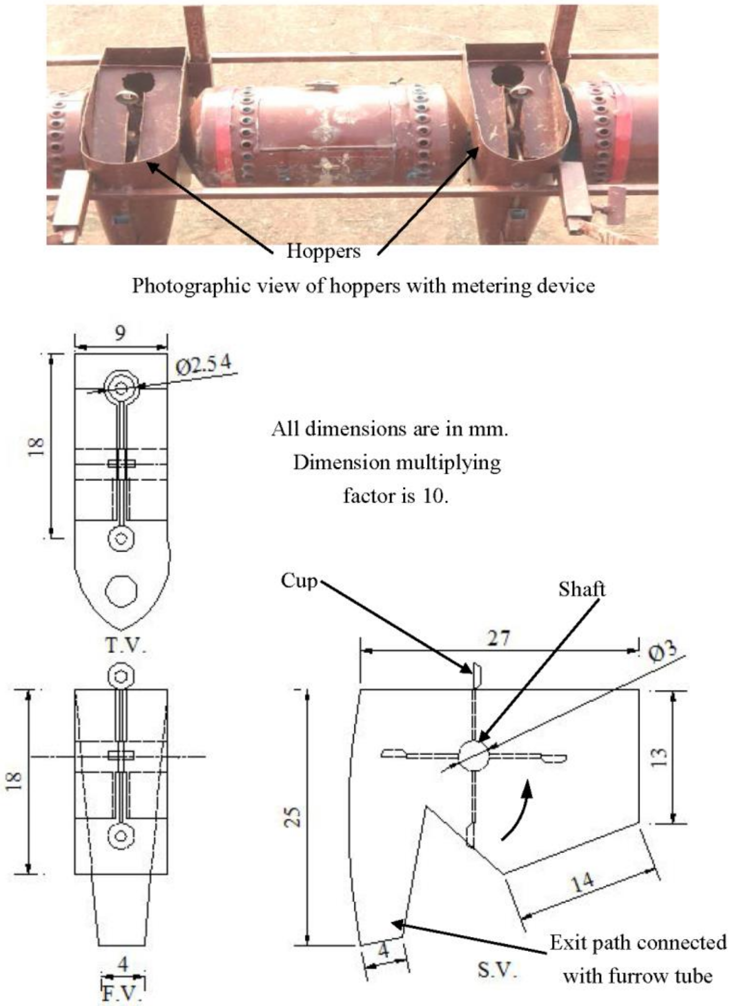


Figure 1 Different views of hopper with metering device

Furrow opener is designed and attached with the applicator to place the GU at a desired depth. The length of furrow opener is 80 mm and it is made of MS square (20 mm × 20 mm) bar. Tip of the furrow opener is pointed and sharp enough to cut the soil. The bar is welded with 0.18 m long M.S square (20 mm × 20 mm) hollow shaft. The adjusting shaft of the furrow opener is attached with the frame of the applicator and makes a provision to set the furrow opener in a desire depth. Different views of the furrow opener are shown in Figure 2.

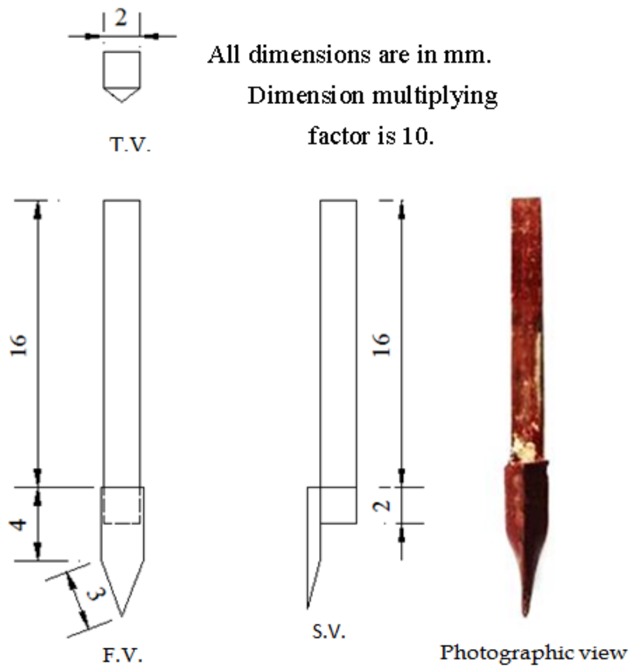


Figure 2 Different views of furrow opener

The furrow closer is made of a MS sheet of 80 mm×120 mm and it is welded with a hollow square (20 mm × 20 mm) shaft. The total length of covering device is 0.38 m. The adjusting shaft of the furrow closer is attached with the frame of the applicator and makes a provision to set the furrow closer in a desire depth. Different views of the furrow closer are shown in Figure3.

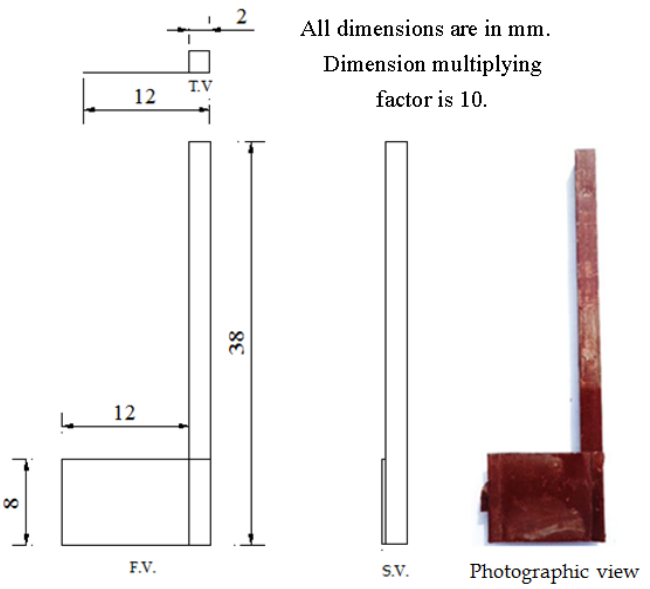


Figure 3 Different views of furrow closer

The pulling handle of the applicator is made of M.S rod and attached with main shaft. It is 0.90 m long and 0.48 m wide. The ends of the handle are fixed with the main shaft to avoid the side sliding but there is a provision to move up and down the handle according to the user's height. The user can use it easily according to his comfortable height for this arrangement. Figure 4 shows the design of handle.

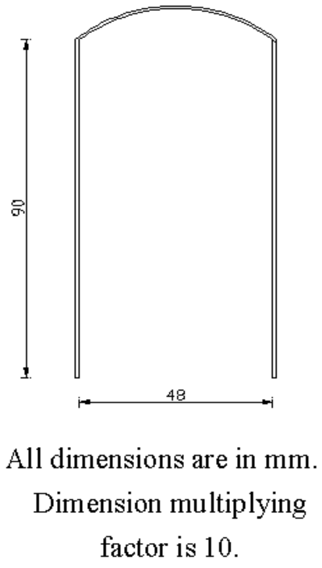


Figure 4 Design of handle

The length and diameter of the drum are 0.25 m and 0.15 m, respectively. There are a number of holes around the drum in two rows. Figure5 shows different views of drum and Figure6 shows the stretch out of the drum.

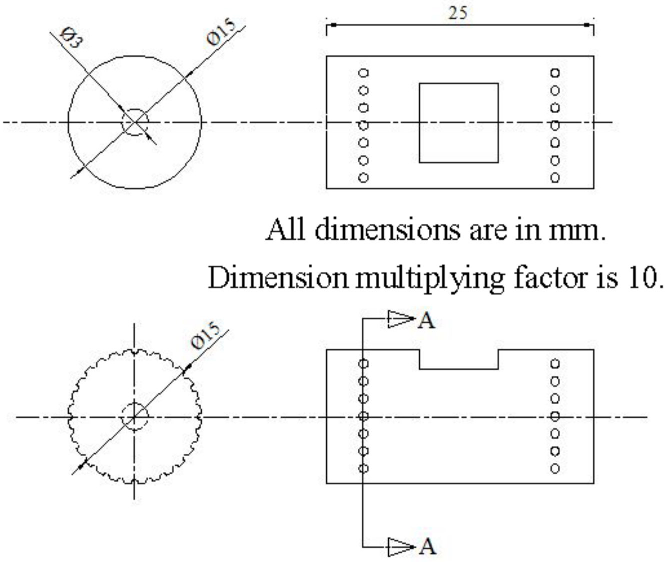


Figure 5 Different views of drum

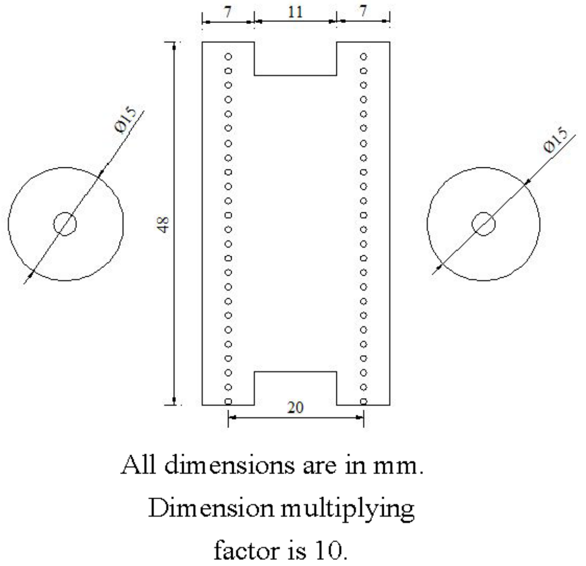


Figure 6 Stretch out of drum

2.3 Working principles of drum seeder with urea supergranule application

When an operator pulls the applicator, the forward movement of the machine rotates the driving wheels which rotate the drum and the metering device in the hopper. One GU is hold in the cup of metering device and dropped on the furrow making by the furrow opener. After that, the furrow closer covers GU with soil. Figure7 shows the complete drum seeder with urea supergranule application and Figure8 presents the working principle of drum seeder with urea supergranule application.

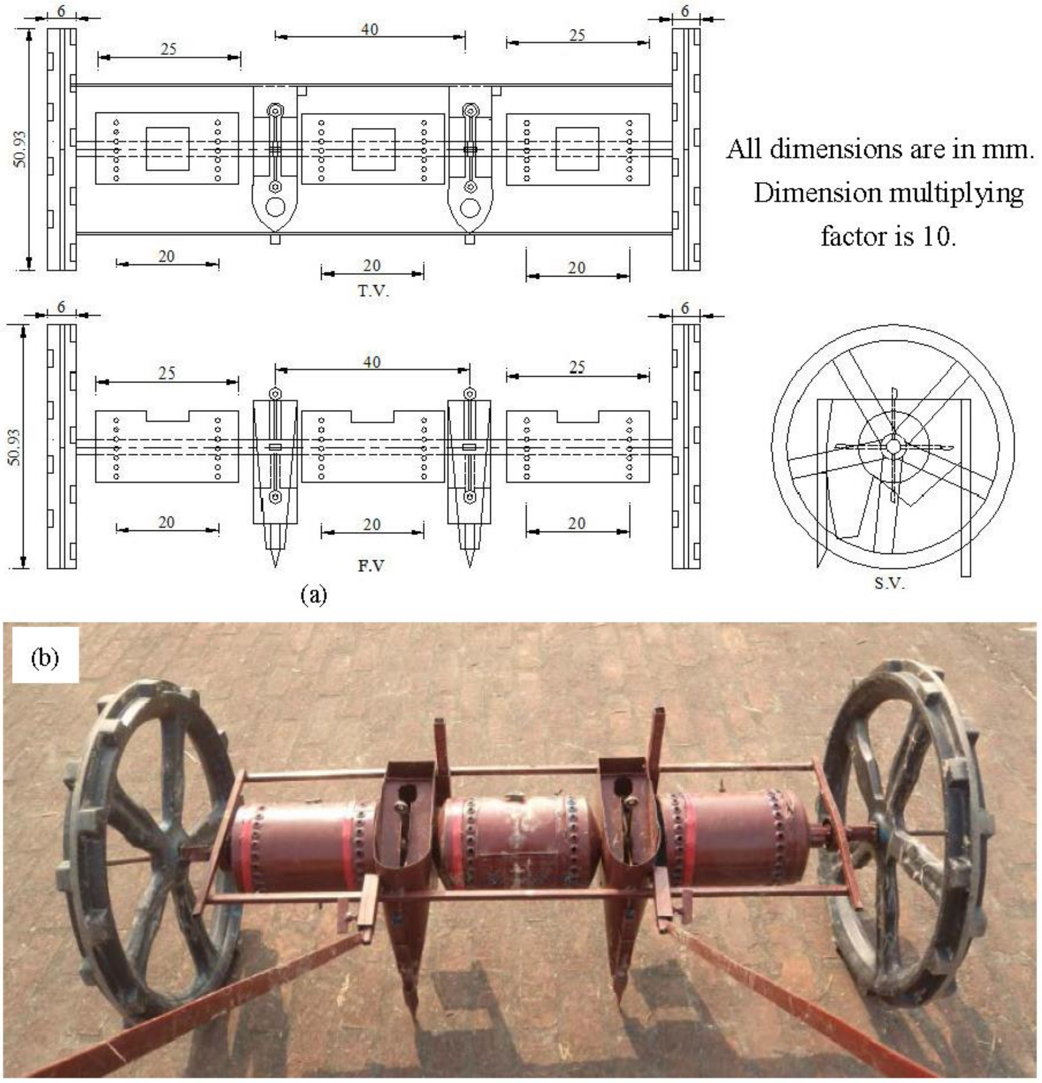


Figure 7 (a) Different schematic views of drum seeder with urea supergranule application, (b) Photographic view of drum seeder with urea supergranule application

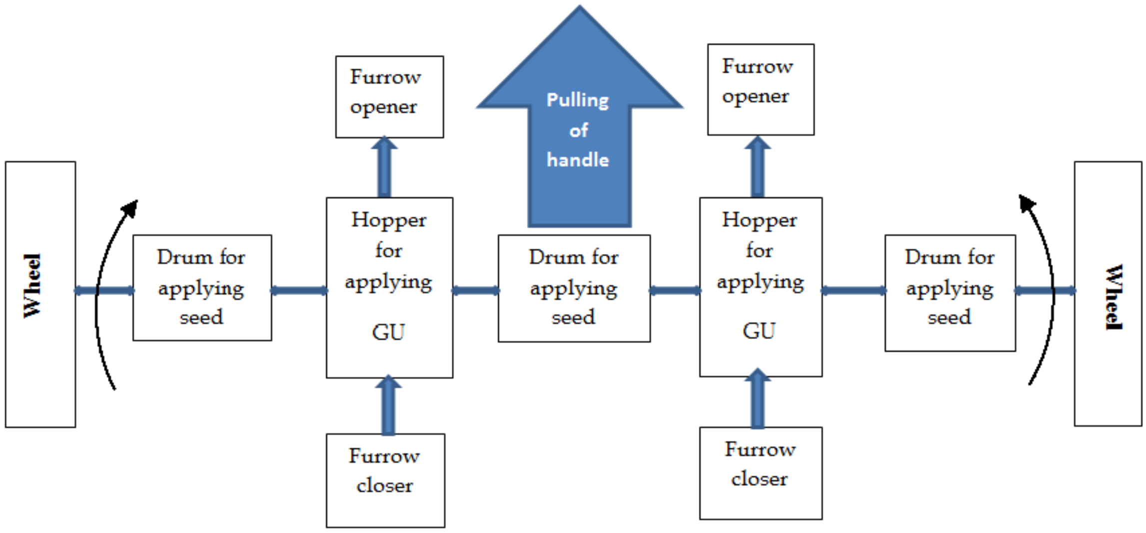


Figure 8 Working principle of drum seeder with urea supergranule application

The volume of hopper for urea granules is 1.7×10^{-3} m^3. The size of the metering cup is designed in such a way so that each cup takes one urea at a time. There is no way to block their passage due to shape of the urea and cup, rubber gate and enough forces applied due to fixed attachment of metering cup with rotating driving shaft.

2.4 Laboratory test of the applicator

Weight of single GU is very important for application properly. Therefore, the weight of each 30 GUs was measured by a digital balance. Size of GU is also important to make the cup of the metering device. The size of each 30 GUs was measured by a slide calipers. The weight of the applicator is also important to carry and maneuver in the field. So it was tried to keep the weight of the applicator as low as possible. The weight of the applicator was measured and data was recorded. The capacity of the applicator was considered as the weight of dropped GU per unit time or area. To determine the capacity of the applicator for applying GU, the applicator was lift from ground. Two polythene bags were fixed with two discharge tubes of metering devices. One person rotates the wheel for 25 times as equivalent to the normal walking speed (1.78 km/hr) in the puddle field. The time require for 25 revolutions of wheel was recorded by a stop watch. Uniform speed of wheel rotation was maintained during the experiment. Then, the weight of GUs which was collected in each bag was measured by an electric balance. The capacity of applicator was estimated by following Equation1:

$$\text{Capacity of the applicator} = \frac{W}{T} \quad \text{(kg/h)} \qquad (1)$$

where, W is total weight of urea dropped in kg and T is the total time to operate the applicator. The hoppers of the applicator were filled with GUs and the metering device was rotated for one minute by turning the wheels. Number of turn was counted and time was recorded by a stop watch. Dropping GU was also counted and recorded. This experiment was done for 10 times. Then the missing and over falling percentage of GU were calculated using the following Equation 2:

$$\text{Over falling or missing \%} = [(N * Y - NG)/ (N * Y)]* 100 \qquad (2)$$

where, N is number of turns of wheel, Y is number of cups in the metering device and NG is total number of GU fallen per minute. Effect of speed on missing and over falling for left and right hoppers was also determined.

The seed rate was determined in the laboratory of Farm Power and Machinery, Bangladesh Agricultural University. The seeder has three drums mounted on a shaft with two ground wheels on either side. There are 28 holes in two rows on the drum. Before starting the laboratory test, seeds were soaked for 1 day. Then, the soaked seeds were kept in the basket and covered by banana leaves for two days for seed germination. Then, the drums of the seeder were filled with germinated seed and the seeder was lift from ground. The drums were rotated 20 times by turning the wheels. The amount of seed fallen from each drum for the given turn was collected and weighed. The times of turning was also recorded with the stopwatch. The seed rate was determined using the following Equation 3:

$$C = \frac{A \times 10000}{3.14 \times D \times W \times N} \quad (3)$$

where, C = seed rate in kg/ha, A = weight of seed in kg for N times of wheel revolutions, D= diameter of wheel in m and W = width of seeder in m.

Effect of amount of seed in the drum on seeding rate was determined. The full capacity of the drum is 2 kg. The drums were filled in different percentage of its capacity (100%, 75%, 50%, and 25% of its full capacity) to determine the effect of amount of seed in the drum on seeding rate. The experiment was conducted for several times. Distribution pattern of seed by pulling the applicator on dry land was also determined. The applicator was run in dry land at normal walking speed. Then the average seed spacing and evenness of spacing were calculated using Equation 4.

$$\text{Evenness of spacing} = \frac{A_{ss} - S_{ss}}{A_{ss}}, \quad (4)$$

where, A_{ss} = Average seed spacing (SS) and S_{ss} = standard deviation of SS.

The required force (P) to pull the applicator was determined in the laboratory using spring balance. Spring balance was fixed in the handle and pulled the applicator. The operation was recorded by a camera. The height and horizontal length of pulling were measured by a tape for calculating the pulling angle (α) as shown in Figure 9. Finally, the draft (d) was determined using Equation 5.

$$d = P \cos\alpha \quad (5)$$

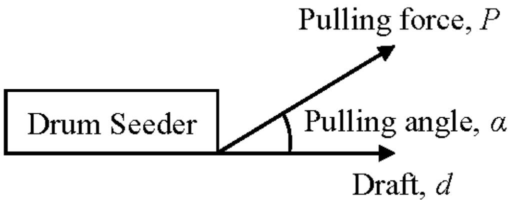


Figure 9 Forces diagram

3 Results and discussions

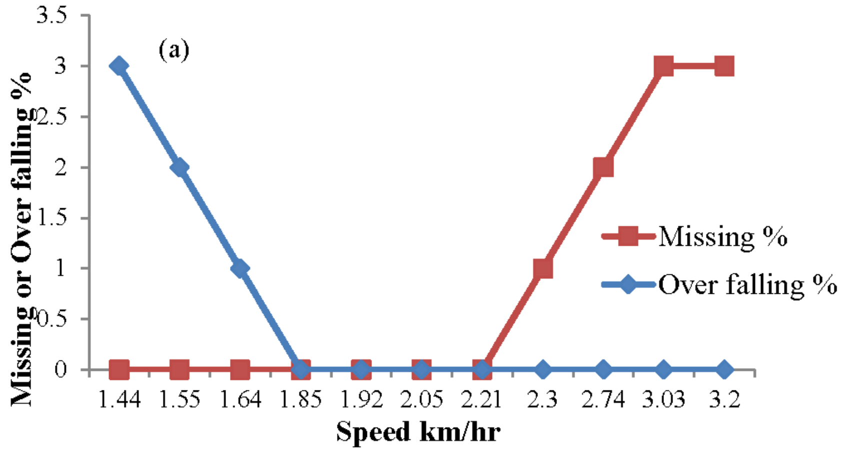
3.1 Missing and overfalling percentages of GU

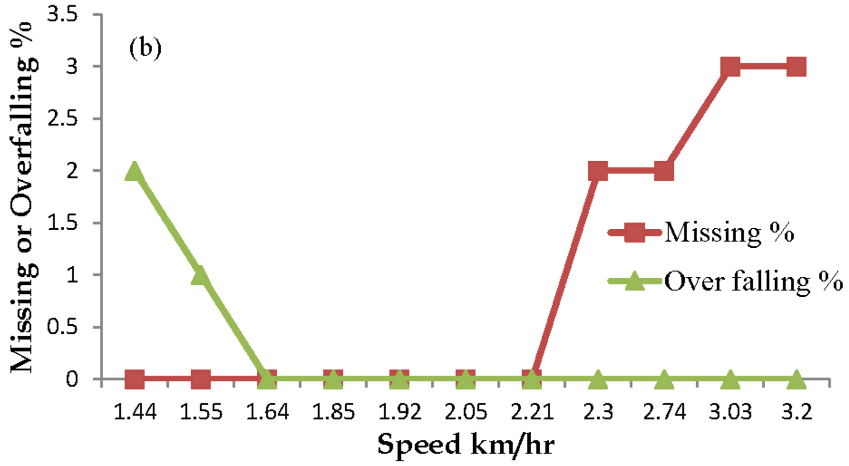
The weight and size of GU were used to determine the dimension of the metering device including cup. It was observed that the maximum, minimum and mean weight of the GU were 3.07×10^{-3} kg, 2.40×10^{-3} kg and 2.70×10^{-3} kg, respectively. It is indicated that weight of GU not varied significantly. On the other hand, it was found that the maximum size of GU was 22.8 mm and the mean size of GU was 21.6 mm with 0.07 mm standard deviation. This result indicated that the size of the sample mostly uniform. However, the diameter of cup of metering device was designed as 22.8 mm to cover the maximum size of the GU. The missing percentage and over falling (more than one GU) of GU, weight of GU, size of GU,

distance between GU to GU, and seed spacing were determined and presented in Table 1. Maximum missing percentage and over falling percentage for both the hoppers were found 3%. According to Figure10, there is a relation between missing and over falling percentages with operator speed. Over falling was occurred due to small sizes of GUs. On the other hand, at high speed, cup in the metering device is failed to bring GU. This is the reason of missing of GU during high speed operation. It is observed that the over falling percentage is higher at low speed in both the hoppers. On the other hand missing percentage increases with increasing the speed after a particular limit. Therefore, it is possible to recommend the operator about the range of speed for operating the applicator. Based on the experimental results as shown in Figure 10, a speed in the range of 1.85 to 2.21 km/hr can be considered for obtaining good performance of the applicator.

Table 1 Missing and over falling percentage of left and right hoppers, weight of GU, size of GU, distance between GU to GU, and seed spacing

Parameters	Missing %		Over falling %		Wt. of GU, ($\times 10^{-3}$ kg)	Size of GU (mm)	GU to GU distance (m)	Seed spacing (mm)
	Left hopper	Right hopper	Left hopper	Right hopper				
Minimum	0.00	0.00	0.00	0.00	2.40	20.0	0.37	2
Maximum	3.00	3.00	3.00	2.00	3.07	22.8	0.43	60
Mean	0.81	0.90	0.54	0.27	2.70	21.6	0.40	21
Standard Deviation	1.25	1.30	1.03	0.65	0.16	0.07	1.71	1.28





re 10 (a) Effect of speed on missing and over falling percentage of left hopper, (b) Effect of speed on missing and over falling percentage of right hopper

3.2 Distribution pattern of granular urea in field

Machine was operated in a 17 m × 7.3 m size plot to find the distance between dropped GU, lap time and turning time. The average distance between GU to GU on dry land for both the hoppers was 0.40 m. The average operating speed and time losses for turning in dry land are 1.78 km/hr and 5 s, respectively. In order to observe the performance of applicator in field condition, the applicator was run over dry land at normal walking speed. Distribution pattern of GU on dry land for left and right hopper are shown in Figure 11. Finally the applicator was operated in the puddle land in the farm to find the field capacity and field efficiency as present in Table 2.

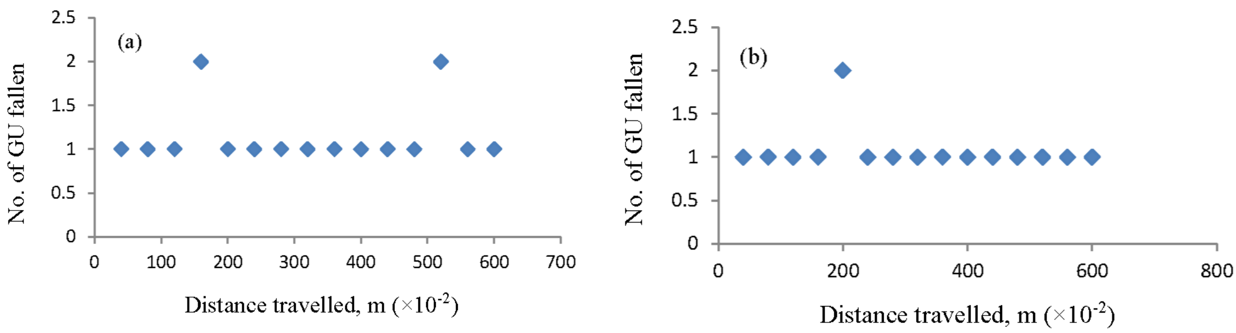


Figure 11 (a) Distribution pattern of GU in dry land, (b) Distribution pattern of GU in dry land

Table 2 Specifications of developed drum seeder with urea supergranule application

Particulars	:	Description
Name	:	Pull type drum seeder with urea supergranule application
Source of power	:	Manual
Source of power for driving	:	Manually pull
Metering mechanism	:	Driving wheel
Weight of the machine	:	12 kg
Dimension of the machine: Length, width, and height (over ground)	:	1.5 m, 1.35 m, and 0.2 m (0.8 m for GU)
No. of operator required	:	1
Traveling speed in dry land and in puddle land	:	2.21 km/hr, 1.78 km/hr
Metering system	:	4 cups rotate with shaft
Capacity of each hopper	:	2 kg
Capacity of each drum	:	2 kg
Material of hopper	:	Mild Steel sheet
GU dropping mechanism	:	Gravitational force
Attachment of furrow opener and covering device	:	M.S rod
Ground wheel diameter	:	0.51m
Material of handle	:	M.S rod
Recommended traveling speed	:	1.85 - 2.21 km/hr
Average pulling force	:	108 N
Draft	:	73 N
Required power (maximum)	:	0.02 kW
Theoretical field capacity (GU)	:	0.2 ha /hr
Actual field capacity (GU)	:	0.14 ha/hr
Field efficiency (GU)	:	78.4%
Theoretical field capacity (Seed)	:	0.4 ha /hr
Actual field capacity (Seeds)	:	0.33 ha /hr
Field efficiency (Seeds)	:	87%

3.3 Distribution pattern of paddy seed in field

The plot 17 m × 2.6 m size was selected for direct seeding. The distribution pattern of seed over dry land is shown in Figure 12(a). A measuring tape was used to measure the distance between seed to seed as shown in Figure 12(b). The space between the seeds was measured and recorded. Finally the applicator was operated in the puddle land in the farm to find the field capacity and field efficiency as shown in Table 2.

Figure 12 (a) Distribution pattern of seed on dry land, (b) Distribution pattern of seed on white paper

3.4 Relationship between amount of seed in the drum and seeding rate

A relationship was found between amount of seed in the drum and seeding rate as shown in Figure 13. The seed rate was 25.5 kg/ha when the drum was full of seeds (2kg) and it was 65 kg/ha when the drum was fill up with one-fourth (0.5kg) of its capacity. This result indicates that the seeding rate increases with decreasing the amount seed in the drum.

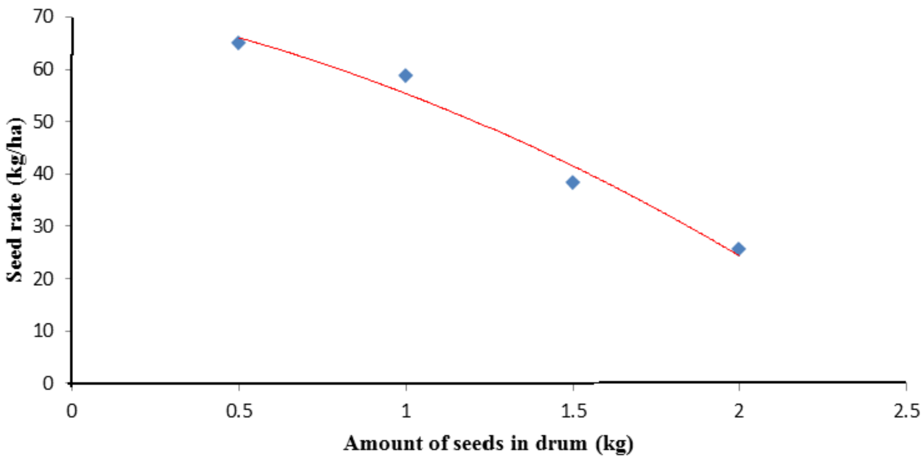


Figure 13 Relationship between the amount of seeds in the drum and seeding rate

3.5 Performance of furrow opener and covering device

The performance of the furrow opener and covering device were observed during the test of the applicator in the puddle field. It was observed that both the devices were performed properly**.**

3.6 General specifications

The weight of the whole applicator is only 12 kg which is easy to carry from one field to another field. Based on the pulling angle as 47^0 and pulling force as 108 N, the required average draft is 73 N using Equation 5 and 1.78 km/hr speed can be considered when the moisture content of the soil is 34%. Therefore, one man or women can pull the machine very easily. The construction of applicator is easy and simple. It has following advantages: i. easy to manufacture, ii. require less energy, and iii. easy to adjust and operate. The complete specification of the applicator is present in Table 2.

4 Conclusions

Design of a pull type drum seeder with urea supergranule application is simple and its operation is very easy. It requires very small force (108N) to pull. Maximum missing percentage and over falling percentage for both the hoppers were found 3%. The maximum average distance between granular urea to granular urea was found 0.4 m. The seed rate was 25.5 kg/ha when the drum was full of seeds and it was 65 kg/ha when the drum was filled up with one-fourth of its capacity. The field capacity of the applicator was 0.14 ha/hr for applying granular urea at a speed of 2.21 km/hr and field efficiency was 78.4%. The field capacity of the applicator was 0.33 ha/hr for applying seeds and field efficiency was 87%. So it can be concluded that the drum seeder with urea supergranule application could be successfully introduced for small rural farmers in Bangladesh.

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References

Alam, M., M. R. Ali, M. A. Rabbani, and A. B. M. M. H. Khan. 2006. Design and development of a drum Seeder. *Journal of Progressive Agriculture*, 17(2): 203-212.

Alam, M., S. Sarker, and M. A. Momin. 2007. Profitability of rice production using drum seeder. *Journal of Bangladesh Agricultural University*, 5(1):135-144.

Bansal, R. K. and R. Leeuwfstein. 1987. Performance evaluation of oscillating trough-type fertilizer applicator. *Journal of Agricultural Engineering Research*, 36(2): 101-114.

Gaudin, R. 2012. The kinetics of ammonia disappearance from deep-placed urea supergranules (USG) in transplanted rice: the effects of split USG application and PK fertiliser. *Paddy and Water Environment*, 10(1):1-5.

Gaudin, R. and G. D’Onofrio. 2015. Is the source-sink relationship in transplanted rice receiving deep placed urea supergranules dependent upon the geometry of transplanting? Paddy and Water Environment, doi: 10.1007/s10333-014-0461-z.

Hoque, M. A., M. A. Wohab, M. A. Hossain, K. K. Saha, and M. S. Hassan. 2013. Improvement and evaluation of Bari USG applicator. *Agricultural Engineering International: CIGR Journal*, 15(2):87-94.

IFDC. 2007. Report on fertilizers and agricultural intensification IFDC”s experiences, IFDC-Asia Division.

NAP. 2009. National agricultural policy report on fertilizer application, Government of the People’s Republic of Bangladesh, p-20.

Nishiura, Y. and T. Wada. 2012. Rice cultivation by direct seeding into untilled dry paddy stubble: proposal of new seeding method and germination rate with that. *Engineering in Agriculture, Environment and Food*, 5(2):65-70.

Salam, M. A., M. A. Kabir, and M. N. Miah. 1992. Direct-seeding of modern variety as late season rained lowland rice in Bangladesh. *Bangladesh Rice Journal*, 3(1&2):11-13.

Savant, N. K. and Stangel P. J. 1990. Deep placement of urea supergranules in transplanted rice: principles and practices. *Fertilizer research*, 25(1):1-83.

Singh, R. D., B. Singh, and K. N. 1983. Singh. Evaluation of IRRI pantnagar bullock-drawn, six row paddy seeder. *Agricultural Mechanization in Asia, Africa and Latin America*, 14(3): 15-20.