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Design and development of manually operated seed cum fertilizer drum seeder for finger millet (*Eleusine coracana* (L.) Gaertn) nursery raising

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Abstract
Finger millet (*Eleusine coracana* (L.) Gaertn) is mainly cultivated by transplanting method by using seedlings raised in the nursery grown by manual seed drilling or broadcasting in the field. The small size of the seeds hinders uniform metering. Usually more seeds are dropped manually for the assurance of getting sufficient seedlings. The densely raised seedlings may not have healthy and uniform growth. This results in discard of unhealthy seedlings that in turn is the loss of seeds and the nutrients supplied. The mechanical transplanting requires uniform seedlings. Considering this, a four row manually operated seed cum fertilizer drum seeder has been developed for the uniform distribution of seeds in the nursery bed for proper growth of seedlings. The main frame of the drum seeder is made up of MS while the drums are made up of PVC pipes. In single filling of drums, the drum seeder can grow seedlings required for transplanting one hectare area. It was tested with two different diameter ground wheels (165 and 230 mm as D_1 and D_2), three different operating speeds (1, 1.5 and 2 km/h^{-1} as S_1, S_2, S_3) and two different numbers of orifices on the drum (12 and 24 as H_1 and H_2). The drum seeder was tested in laboratory in the jacked condition to determine the seed rate. It was further tested in the field on sticky plate and in actual working condition to determine the seed uniformity and seedling density. The required plant population to satisfy the transplanting need was obtained when the seed drill was operated with 24 orifices drum at 1.5 km/h^{-1} speed using 165 mm diameter wheel and at 2 km/h^{-1} speed using 230 mm diameter wheel.

Keywords: Manually operated, drum seeder, finger millet, nursery raising

Introduction
Finger millet is mostly grown as a transplanted crop. Seedlings are grown in nurseries before being transplanted into the main field. The seeds are manually spread in the 1/10th of the area to be transplanted, either by broadcasting or by line sowing (without using a seed drill). The seedlings are then manually transplanted into the main field when they are 25 to 30 days old (Anon., 2017) [1]. The experience and skill of the person sowing the seeds and fertilizer affects the seed and fertilizer application rate. Carlson and Clay (2016) [2] advocate sowing 10% extra seeds than the required or planned plant population in the field. Farmers usually sow more seeds and fertiliser than is required and work in a bending position. Manual sowing takes a long time and requires a lot of effort. Manual control of seed rate and fertiliser application is impossible, resulting in inconsistent seed density and fertiliser application. The growth of the seedlings impeded as a result of the densely crowded seedlings. There's a better chance of preventing disease from spreading (Carlson and Clay, 2016; Tewari, 2009) [2, 3]. As a result, there must be a balance between the area under the nursery and the development of healthy seedlings in order to save money. By spreading the seeds with a mechanical device, the seedling density and fertiliser application may be maintained, resulting in healthy seedlings.
Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli (Dr BSKKV, Dapoli) has proposed growing seedlings in nursery in 10 cm rows in 1/10th of the area to be transplanted with a seed rate of 5 to 6 kg/ha^{-1} for finger millet farming. A drum seeder is the better option because of the size and shape of finger millet seeds and fertiliser granules. A manual seed cum fertiliser drum seeder has been devised and developed to maintain seed density, apply fertiliser, and reduce labour and time requirements for nursery sowing.

Materials and Methods

While designing the drum seeder, the following design considerations were made

1. It should meter seeds and granular fertilizer evenly at optimum depth and cover soil properly.
2. It should be easy to fabricate, operate and maintain.
3. It should be light in weight to operate by a single person.
4. The nursery of seedlings on 1/10th of the hectare require to cover one hectare area of cultivation.

Physical parameters of seeds like size, volume and weight were considered for designing drum size and orifice diameter on the drum for easy passage of seeds (Table 1). Orifice spacing on drum and diameter was decided based on spacing of seeds required on field.

Table 1: Physical properties of finger millet seed (CvDapoli 1), Powar, (2018)

Sr. No	Parameters	Moisture content, per cent	
		7.05	10.21
1	Geometric mean diameter, mm	1.41	1.46
2	Sphericity	0.91	0.92
3	Volume, mm^3	1.62	1.75
5	Thousand grains weight, g	2.29	2.40
6	Bulk density, kg m^{-3}	749	724
7	True density, kg m^{-3}	1515	1429
8	Porosity, per cent	50.59	49.32
9	Angle of repose, degree	20.50	22.95

A. Design of manually operated seed cum fertilizer drum seeder for finger millet

a. Design of seed drum, (Chate, 2017) [4]

Volume of seed drum assumed 10% more than volume of required quantity of seeds.

Volume of seed drum is given by,

$$V_d = 1.1\ V_s \quad (1)$$

$$V_s = \frac{W_s}{Y_s} \quad (2)$$

V_d = Volume of seed drum, cm^3,
V_s = Volume of seed, cm^3,
W_s = Weight of seed, g,
Y_s = Bulk density of seed, g cm^{-3},
Putting value of V_s in equation (1)

$$V_d = \frac{1.1 W_s}{Y_s} \quad (3)$$

b. Design of fertilizer drum

Because the size of ammonia granules is identical to that of finger millet seeds, the same size drums and orifice were utilised for seed and fertiliser. Instead of one orifice line per row, three orifice lines were created for fertilizer metering.

c. Seed and fertilizer metering

For seed metering, 12 and 24 orifices evenly spaced along circumference were created on each seed drum for sowing two rows of seeds at two different seed densities. Seed metering was done in four rows using two drums. The diameter of finger millet seeds was used to determine the orifice size i.e. 3 mm. The fertiliser metering drums were built in a similar manner as the seed metering drums, with minor differences. The fertiliser metering drum has three lines of orifices for each row, and two drums were utilised for the fertiliser metering in four rows.

d. Design of furrow openers

The size of the manually operated seed cum fertilizer drum seeder for finger millet was decided based on the average available manual power i.e. 0.1 hp (0.0746 kW). The furrow opened by furrow opener was considered trapezoidal in shape.
Top working width of furrow opener, a = 52 mm,
Bottom width of furrow opener, b = 25 mm and
Cutting depth of the furrow opener, h = 35 mm

$$\text{Cross section of furrow opener (A)} = \left(\frac{a+b}{2}\right) \times h \quad (4)$$

$$= \left(\frac{5.2+2.5}{2}\right) \times 3.5 = 13.5 \text{ cm}^2 \quad (5)$$

The value of the actual average soil resistance was calculated by the following formula (Varshney *et al.*, 2004) [6].

$$F_x = A \times P_k \quad (6)$$

Where,

A = Cross section of furrow, cm^2
P_k = Specific soil resistance for the light soil, kg cm^{-2}
Specific soil resistance P_k when sowing to a depth of 15 cm under light, medium and heavy soils are 0.12, 0.15 and 0.20 kg cm^{-2}, respectively (Varshney *et al.*, 2004) [6].
Therefore,

$$F_x = A \times P_k$$

= 13.5 × 0.12 = 1.62 kgf… for light soil

The soil resistance was assumed 3 times higher than actual average soil resistance (Fx) considering the obstacles in the field that may occur during operation.

Draft at the tip of tine (Dt) = Fx × (3 times) kgf (7)
Dt = 1.62 × 3 = 4.86 kgf

Total draft = 4.86 × 9.81 N= 47.68 N

Maximum speed of operation was considered to be 1.5 km/h^{-1} (0.42 m s^{-1})

Power = Draft (N) × Speed (m s^{-1}) (8)

= 47.68 × 0.42 = 20.02 W = 0.02 kW

$$\text{Number of furrows} = \frac{\textit{Available power}}{\textit{Operational power per row}} \quad (9)$$

$$= \frac{0.0746}{0.02} = 3.73 \text{ row} = 4 \text{ rows}$$

Therefore, four furrow openers for seed cum fertilizer drum seeder can be operated with available power.

e. Design of main frame of the manually operated seed cum fertilizer drum seeder for finger millet

The main frame of the manually operated seed cum fertilizer drum seeder for finger millet was designed to accommodate the handle to pull the unit, axles of the front and the rear wheels, soil covering plate and the two pairs of drums for seed and granular fertilizer respectively.

Table 2: The configurations of ground wheel diameter and orifice position on drum for seed metering

S. N.	Ground wheel diameter, mm and orifice position on drum	Orifice spacing on drum, mm	Theoretical seed spacing (Ss) in row, mm	Seed rate, kg/ha
A	165			
1	12	19.6	43.12	5.81
2	24	9.8	21.56	11.90
B	230			
3	12	19.6	60.10	3.96
4	24	9.8	30.05	7.93

f. Design of ground wheel

In addition to the orifice spacing on the seed and fertilizer drums for seed and fertilizer metering respectively i.e. to change the seed spacing along the row, wheels of two different diameters i.e. 230 mm and 165 mm were used. The theoretical seed spacing (mm) was calculated considering the number of orifices on the seed drum and assuming the seeds will drop only from orifices at the bottom of drum while rotating (Table 2).

$$\text{Orifice spacing (mm)} = \frac{\pi \times \textit{Drum diameter (mm)}}{\textit{No. of orifices on drum}} \quad (10)$$

The ratios of wheel diameter to the drum diameter were

1.	$\frac{230}{75} = 3.066$	2.	$\frac{165}{75} = 2.2$

Theoretical seed spacing (mm)

$$= \frac{\textit{Ground wheel diameter (mm)}}{\textit{Drum diameter (mm)}} \times \textit{Orifice spacing (mm)} \quad (11)$$

The theoretical seed spacing on the ground with respect to the use of ground wheel and the orifice spacing on the drum was calculated (Table 2).

The seed spacing at the recommended seed rate and the row spacing for nursery raising in 1/10th of hectare area can be found out on following assumptions

Seed rate = 5.5 kg/ha^{-1}
Area to be sown = 1/10 ha = 10000/10 sq. m = 1000 sq. m.
The width of seed drill = 4 × 0.1 = 0.4 m

$$\text{Quantity of seed per meter per row, g m}^{-1}\text{ row}^{-1} = \frac{5.5 \times 1000}{1000/(0.4) \times 4} = 0.55$$

B. Development of manually operated seed cum fertilizer drum seeder for finger millet

a. Main frame

The main frame is fabricated using MS flat (40 x 5 mm) and MS rod (12 mm) dia for mounting two drums for seed, two drums for fertilizer, four furrow openers, seed covering plate and a handle (Fig 1).

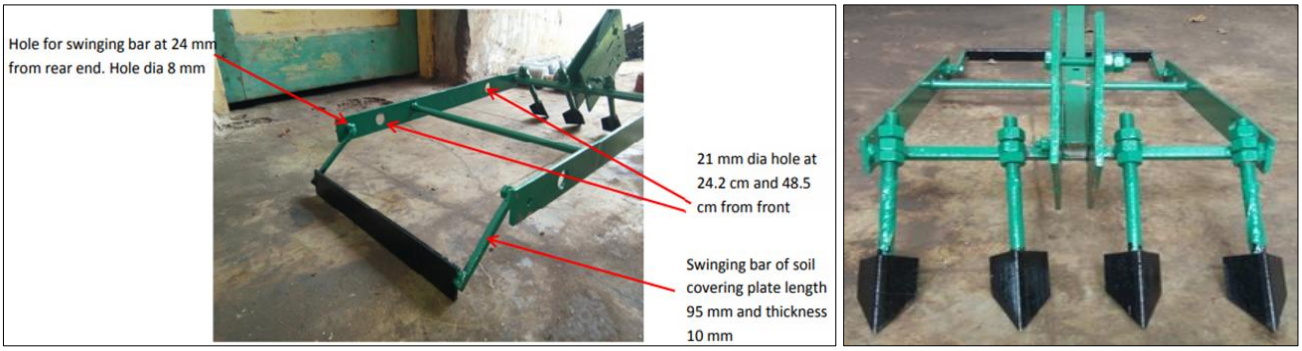

Fig 1: Main frame of the drum seeder with furrow opener

b. Development of seed and fertilizer drums

PVC pipe with a diameter of 75 mm was used to make seed and fertiliser drums (Fig. 2 and 3). The seed and fertiliser metering orifices were made on the drum according to the design. Two fertiliser metering drums were mounted on the front axle, while two seed metering drums were mounted on the rear axel, allowing the drums to revolve with the axle. The volume of the drum is large enough to hold seed for seeding 0.095 ha of nursery land, which is enough for transplanting on 0.95 ha, or 1 ha, in one fill.

Fig 2: Seed metering drums fitted on PVC pipe

Fig 3: Fertilizer metering drums fitted on PVC pipe

Fig 4: Seed and fertilizer drums mounted on the main frame

c. Arrangement of seed and fertilizer drums

The front set of drums is for drilling granular fertilizer while the rear one is for drilling seeds (Fig 4). The unit has a soil covering plate at its rear end to cover soil on the seeds drilled in the rows. One handle is provided from front side to pull unit.

Fig 5: Furrow openers of the manually operated seed cum fertilizer drum seeder for finger millet

d. Furrow openers

As per design, four furrow openers are fabricated using MS rods 12 mm ϕ and MS angle 25 × 25 × 5 mm. The furrow openers are adjustable for depth of furrow as per need (Fig 5).

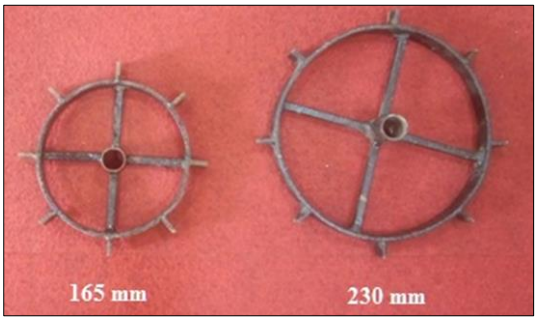

Fig 6: Ground wheels of the manually operated seed cum fertilizer drum seeder for finger millet

e. Ground wheel

Two ground wheels of diameter 230 mm and 165 mm were made using MS flat 25 x 5 mm and fixed on the axle with cotter pin (Fig 6). The wheels can be mounted on axle and secured with the cotter pin.

Fig 7: Arrangement for changing the angle of the handle in vertical plane

Fig 8: Developed manually operated seed cum fertilizer drum seeder for finger millet for nursery raising in operation

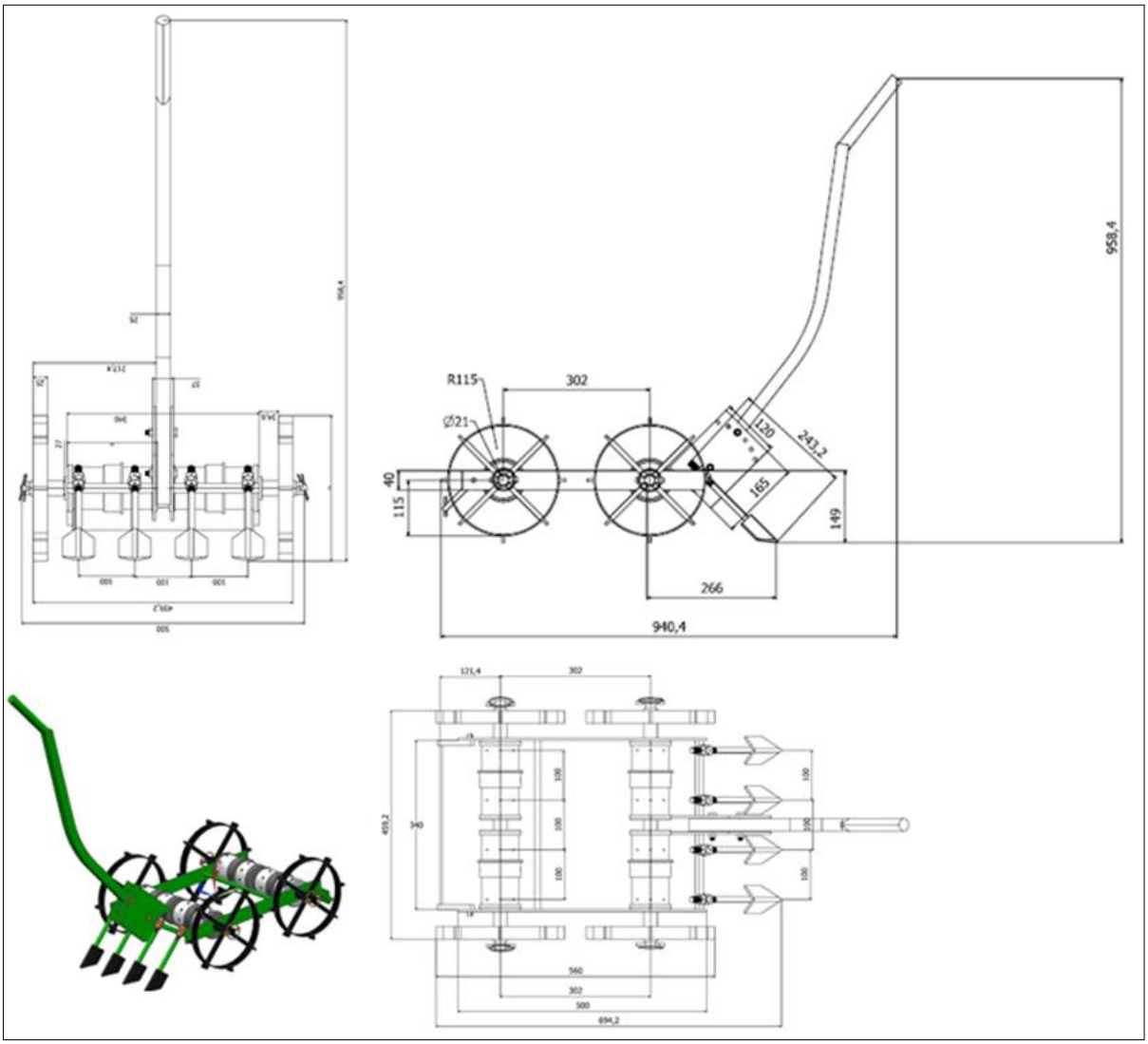

Fig 9: Details of developed drum seeder cum fertilizer applicator for finger millet nursery raising

f. Handle

The handle is fabricated with a 20 mm square GI pipe of 91.5 cm length having a piece of circular pipe of 25 mm dia. and 19 cm length fitted at the extreme for grip. An arrangement is made for changing the angular position of the handle in the vertical plane (Fig 7) as per operator' height. The overall specifications of the developed drum seeder are given in Table 3. The overall view of the fabricated manually operated seed cum fertilizer drum seeder for finger millet seed given in Fig 8 and 9.

Table 3: Specifications of developed manually operated finger millet drum seed cum fertilizer applicator

S. N.	Particulars	Parameter	Values
1	Overall dimensions	Length, mm×Width, mm ×Height, mm	1070 × 520 × 1100 with 165 mm wheel 1070 × 520 × 1070 with 230 mm wheel
		Empty Weight, kg	12.63 kg with 165 mm wheel 13.73 kg with 230 mm wheel
2	Ground drive details	No. of wheels	4
		Materials and type of wheels	MS and Lugged wheel
		Effective diameter, mm	165, 230
3	Metering mechanism	Seed metering drum (material PVC)	3 mm dia. Orifices
		Fertilizer metering drum (material PVC)	3 mm dia. Orifices
		Number of orifices on the drum	12, 24
		Number of drums for each seed and fertilizer	2
		Size of drum	75 mm ×140 mm
4	Theoretical Drum capacity	Seed Drum capacity, kg	0.360
		Fertilizer Drum capacity, kg	0.480
5	Furrow openers and covering device	No. of furrow openers	4
		Furrow spacing, mm	100
		Width of furrow opener, mm	52
		Seed covering device	Leveler

C. Evaluation of manually operated finger millet drum seeder cum fertilizer applicator

Independent variables

1. No. of orifices on drum: 12 (H_1) and 24 (H_2)
2. Diameter of ground wheel, mm: 165 (D_1) and 230 (D_2)
3. Speed of operation, km/h: 1 (S_1), 1.5 (S_2) and 2 (S_3)

Dependent parameter: Seed rate

A finger millet seeder cum fertilizer applicator was developed for finger millet nursery raising to standardize nursery raising method. It was designed, developed, and evaluated in laboratory at Department of Farm Machinery and Power, CAET, Dapoli and on farm at Research Plot of Department of Agronomy, DBSKKV, Dapoli. The results obtained are discussed below.

a. Laboratory tests of manually operated finger millet drum seeder cum fertilizer applicator in jacked condition

The seed rate observed to increase with the forward speed of seeder. It also increases with increase in diameter of ground wheel. This may be due to the centrifugal force that forces seed outside through the orifice at higher rotational speed (Ratnayake and Balasoriya, 2013, Poschel, and Buchholtz. 1995). This may also be due to seed roundness and higher vibrations which occurred at higher speed. In general, factors such as orifice size, spacing between the orifices on the drum, percentage fill of drum, and speed of operation significantly affected the flow rate of seeds through the orifices (Prasanna Kumar *et al.*, 2004).

b. Laboratory tests of manually operated finger millet drum seeder cum fertilizer applicator on sticky plate

1. Seed distribution efficiency

The seed distribution efficiency was observed to be maximum with $H_2D_1S_3$ (24 orifices, 160 mm wheel dia., 2 km/h forward speed) combination. In drum seeder, seed distribution efficiency observed to be increased with the increase in forward speed of the seeder and ground wheel diameter. As per the recommended seed rate and row spacing of 10 cm for raising finger millet nursery seedling, quantity and number of seeds to be dropped per meter per row was 0.55 g and 220 respectively. Accordingly, seed spacing was 0.45 cm. Seed distribution refers to planting of seeds according to a predetermined pattern (see Soza *et al.*, 2004). The maximum seed distribution efficiency of 43.64% was observed with $H_2D_1S_3$ followed by 40.91% with $H_2D_1S_2$ operating conditions. The least seed distribution efficiency of 11.27% was observed at $H_1D_2S_2$ operating combination. The lower distribution efficiency may be due to the free flowing, small size, round shape of seeds and vibrations on uneven field condition. Similar results were also observed for paddy seeds through orifices by Prasanna Kumar *et al.*, 2004, Sivakumar *et al.*, 2003 and Sivakumar *et al.*, 2005.

2. Uniformity coefficient

The uniformity coefficient was observed to be more than 0.9 for all trials. It was maximum 0.97 for $H_2D_1S_1$, $H_2D_1S_2$ and $H_2D_1S_3$ followed by 0.96 for $H_1D_1S_3$ and $H_2D_2S_3$ operating conditions. It indicates that uniformity coefficient is higher for 24 orifices than 12 orifices. It was also observed that uniformity coefficient increased with forward speed for all combination of operating parameters. The falling of seeds on grease plate was affected due to point from which seeds were leaving orifice. This affects falling of seed on grease plate and affects seed spacing in line and uniformity in metering of seed in line. (Asl *et al.*, 2019). The uniformity coefficient up to 0.97 was recorded by Rahmati and Hajiahmad, 2008 for Paddy.

3. Depth of seed placement

The depth of seed placement was observed to vary between 1 to 2 cm, which is required for such small size seeds. The desired depth of placement of seed is 12 to 13 mm for proper germination and growth (Anonymous, 2017d). The minimum and maximum depth was occurred at $H_2D_1S_3$ and $H_2D_1S_1$ respectively. The operating parameters $H_1D_1S_2$, $H_1D_1S_3$, $H_1D_2S_3$ and $H_2D_2S_3$ showed the desired depth of seed placement. The depth of operation was observed to be decreased with increase in speed of operation. Casão Junior *et al.*, 2000 Mahl *et al.*, 2004 and Silveira *et al.*, 2011 also reported deeper furrows at lower speeds. This may be due to pulling forces acting horizontally more at higher speed than vertically downward forces of drum seeder weight at lower speed. Condition of soil prepared, *i.e.* tilth of soil, moisture content and type of soil might have affected the depth of operation.

4. Plants per sq. meter

It was observed that number of plants/m^2 increases with increase in speed of operation and number of orifices on drum whereas decreases with ground wheel diameter (Sarkar *et al.*, 2019). This may be due to lesser number of revolutions of drum due to larger wheel to cover the same distance created less opportunity for seeds to fall through orifices. The plant density was very high as the seeds were falling from the orifices. As per the recommended seed rate and the area under the nursery, 300 to 450 plants/m^2 are expected. Hence, seedling population obtained within this range can be considered satisfactory because it could satisfy the need of the quantity of seedlings required. The $H_2D_1S_2$, $H_1D_2S_2$, $H_2D_1S_1$ and $H_2D_2S_1$ were the operating parameters that met this criterion. The other operating parameters showed either higher or lower plant population than required. The seedling population less than recommended can be accepted if the seedlings obtained are healthier. Seedling population in nursery can be compromised to get the required seedling quality.

5. Cost of operation

The cost of seeding for raising nursery on one hectare area is Rs 1083.33. As the seedlings nursery is raised on 1/10th of the area to be transplanted, the cost seeding to raise seedlings for transplanting on one hectare area is Rs 108.33.

Conclusions

The manually operated drum seeder cum fertilizer applicator for finger millet for nursery raising was fabricated as per the design and was ready for the field tests. The unit was observed to be easy to use by single operator.

Conflict of Interest

The authors declare that there is no conflict of interest.

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