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Evaluation of Manually Operated Finger Millet (*Eleusine coracana*) Drum Seeder cum Fertilizer Applicator for Nursery Raising

A. A. DEOGIRIKAR[1]*, K. G. DHANDE[2], V. V. AWARE[2], A. G. MOHOD[1], J. S. DHEKALE[3] and A. R. JADHAV[2]

[1]Dept. of Agricultural Engineering, College of Agriculture, Dr. B.S. Konkan Krishi Vidyapeeth, Dapoli - 415 712, Maharashtra, India
[2]Dept. of Farm Machinery and Power, College of Agricultural Engineering & Technology, Dr. B.S. Konkan Krishi Vidyapeeth, Dapoli - 415 712, Maharashtra, India
[3]Department of Agricultural Statistics, College of Agriculture, Dr. B.S. Konkan Krishi Vidyapeeth, Dapoli - 415 712, Maharashtra, India

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Finger millet (*Eleusine coracana*) is generally cultivated by the transplanting method. The seedling nursery is grown on one-tenth of the area to be transplanted with recommended seed rate. Manual sowing is the common practice for nursery raising which is cumbersome and non-uniform. Hence, a manually operated finger millet drum seeder cum fertilizer applicator was designed and developed. It was tested with two different diameter ground wheels (165 and 230 mm), three different operating speeds (1, 1.5 and 2 km h^{-1}) and two different numbers of orifices on the drum (12 and 24). The seed rates were determined with the combinations of these independent parameters in the laboratory under a jacked condition of the seeder and working condition in the field over a sticky plate as well as under field conditions. The seed drill 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 gave sufficient plant population to satisfy the transplanting need.

(***Key words:*** *Drum seeder, Finger millet, Nursery, Seed rate)*

In heavy rainfall areas, finger millet (*Eleusine coracana*) is cultivated by transplanting method for which seedling nursery raised. Normally, seedlings are raised manually in one-tenth of the area to be transplanted as per the recommended seed rate (Anonymous, 2017). The seeds are either broadcasted or drilled manually in the bending posture in the rows at 10 cm spacing across the 1 m wide raised bed of convenient length. The basal dose of fertilizer is applied manually at the time of sowing. The uniform seed drilling of small finger millet seeds in the rows cannot be done manually. In such a case, the seed rate and fertilizer applied and its uniformity depends on the skill of the person sowing it. The seeds are generally sown at a higher seed rate and hence are spread densely which leads to poor germination and subsequent plant establishment in the field. The manual method of sowing is cumbersome and discomfort in nature. The cumbersome and nonstandard method of seed sowing demands the mechanical seed drill. Hence, keeping these facts in view, a drum seeder cum fertilizer applicator for finger millet seeds for nursery raising was designed and developed.

MATERIALS AND METHODS

This study was conducted at the Department of Farm Machinery and Power, Dr. B.S. Konkan Krishi Vidyapeeth, Dapoli, Maharashtra, India during the year 2019 to design and develop a seed drill cum fertilizer applicator for finger millet. The developed finger millet drum seeder cum fertilizer applicator composed of four polyvinylchloride (PVC) drums of 75 mm diameter and 140 mm length, two for seed metering and two for fertilizer metering mounted on two separate PVC pipes of 22 mm inner diameter, 27 mm outer diameter and 340 mm length. The fertilizer drums were mounted on the front axle while the seed drums were mounted on the rear axle. The fertilizer drums have two bands of three lines of 3 mm diameter orifices spaced at 10 cm from the middle line. The seed drums were having two lines of orifices spaced at 10 cm. The arrangement of the drums was made on the unit such that it could drill the seeds and fertilizer in four rows spaced at 10 cm. The unit was a manually pulled type (Fig. 1). Two different sets of drums were made, each for seed and fertilizer according to the number of orifices on it. One

**Corresponding author:* E-mail: amitdeogirikar@rediffmail.com

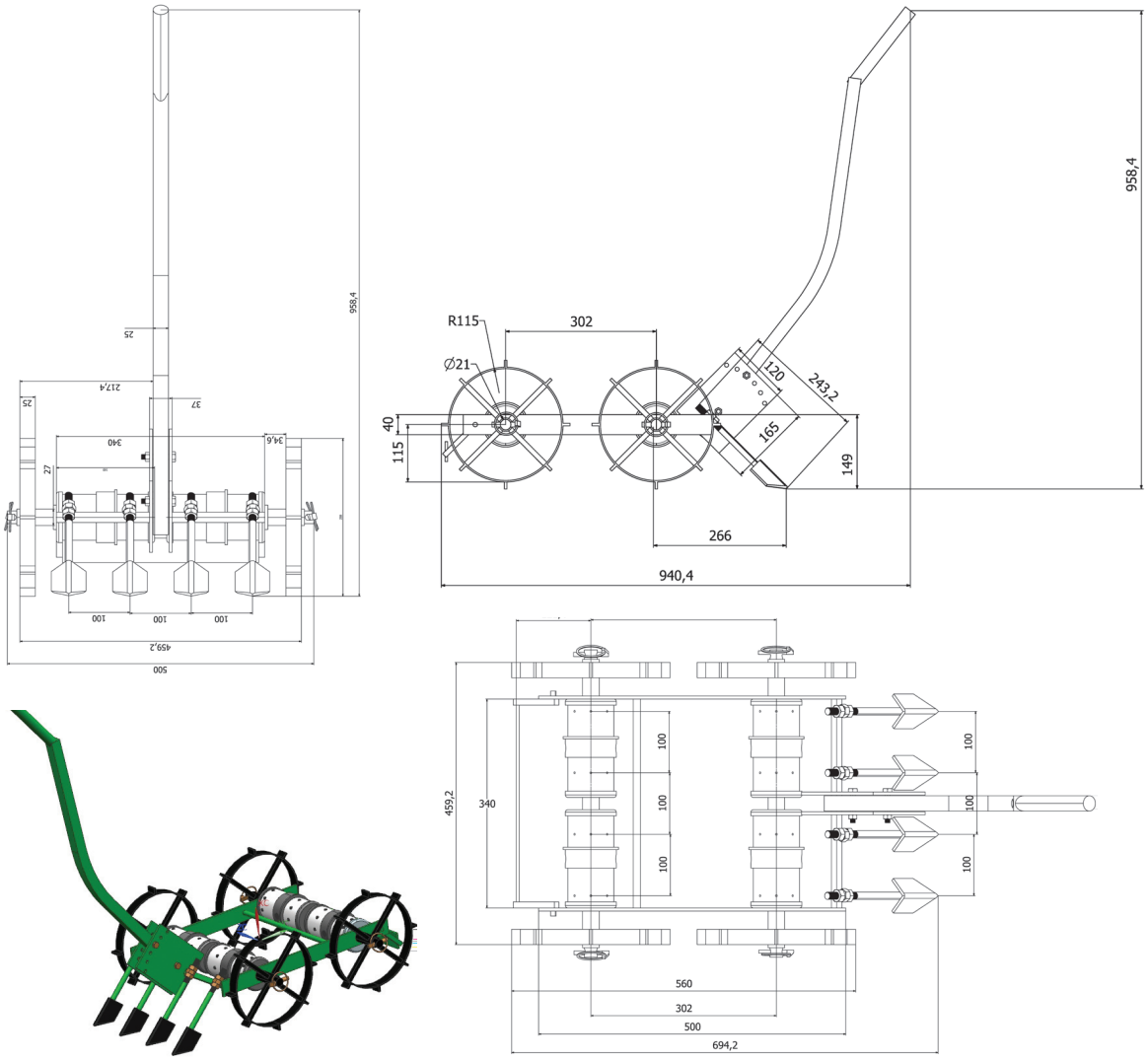

Fig. 1. *Developed drum seeder cum fertilizer applicator for finger millet nursery raising*

set was having equally spaced 12 (H_1) while the other was having 24 (H_2) orifices. Two different diameters of wheels *i.e.*, 165 (D_1) and 230 (D_2) mm were used. The detailed specifications of the finger millet drum seeder cum fertilizer applicator is given in Table 1.

The developed finger millet drum seeder cum fertilizer applicator was tested in the laboratory and in the field to evaluate its performance.

Laboratory tests

The laboratory tests or drum seeder calibration in stationary condition was done for the determination of seed rate and seed uniformity.

Determination of seed rate

The actual seed rate of the drum seeder was determined for the three forward speeds *i.e.*, 1.0, 1.5, 2.0 km h^{-1} (S_1, S_2, and S_3), two different ground wheel sizes *i.e.*, 165 and 230 mm diameter (D_1 and D_2) and two numbers of orifices *viz.*, 12 and 24 (H_1 and H_2) on the drum, respectively. The seed drill was jacked up to rotate the ground wheels freely using the handle for the calculated number of rotations per minute (Equation 1) as per the forward speed and wheel diameter. The seed drums were filled to 3/4th of their capacity at the beginning of the test. The seeds dropped from drums were weighed using a digital weighing balance.

Table 1. *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) Empty weight, kg	1070 × 520 × 1100 with 165 mm wheel 1070 × 520 × 1070 with 230 mm wheel 12.63 kg with 165 mm wheel 13.73 kg with 230 mm wheel
2	Ground drive details	No. of wheels Materials and type of wheels Effective diameter, mm Lug height, mm	4 MS and lugged wheel 165, 230 12.5
3	Metering mechanism	Seed metering drum (material PVC) Fertilizer metering drum (material PVC) Number of orifices on the drum Number of drums for seed Number of drums for fertilizer Size of drum	3 mm dia. orifices 3 mm dia. orifices 12, 24 2 2 75 mm × 140 mm
4	Theoretical Drum capacity	Seed drum capacity, kg Fertilizer drum capacity, kg	0.360 0.480
5	Furrow openers and covering device	No. of furrow openers Furrow spacing, mm Width of furrow opener, mm Seed covering device	4 100 52 Leveler
6	Labour required		1
7	Cost		₹ 2000

$$\text{Rotational speed of ground wheel, rpm} = \frac{\text{Operating speed of drill (m/min)}}{\pi \times \text{Wheel diamter (m)}} \quad (1)$$

The seed rate at different forward speeds using different ground wheels was calculated as

$$\text{Seed rate, kg ha}^{-1} = \frac{\text{Seed collected, g} \times 10000}{\pi \times \text{Ground wheel dia, cm} \times \text{RPM of ground wheel} \times \text{Width of seed drill, cm}} \quad (2)$$

Accordingly, the quantity of seeds collected in g m^{-1} and the average number of seeds dropped m^{-1} length of travel was determined. The theoretical spacing between the consecutive seeds was determined. The test was replicated three times for each speed and the average was calculated. The drums were filled once for each speed test. The seed rate for finger millet as recommended by Dr. B.S. Konkan Krishi Vidyapeeth is 5 to 6 kg ha^{-1}. The theoretical seed rate for the developed seed drill varied from 3.96 - 11.90 kg ha^{-1} (Table 2).

Table 2. *Theoretical seed rate obtained using the combination of the number of orifices on the drum and ground wheel diameter*

Sl. No.	Wheel diameter, mm and orifice position on drum	Orifice spacing on drum, mm	Theoretical seed spacing (Ss) on ground, mm	Seed rate, kg ha^{-1}
A	165 (D_1)			
1	12 orifices (H_1)	19.6	43.12	5.81
2	24 orifices (H_2)	9.8	21.56	11.90
B	230 (D_2)			
1	12 orifices (H_1)	19.6	60.10	3.96
2	24 orifices (H_2)	9.8	30.05	7.93

Based on the assumed 5.5 kg ha^{-1} seed rate, the levels of seed rate decided for testing in the field were 3.96, 5.81 and 7.93 kg ha^{-1}.

Seed rate deviation

The seed rate deviation was taken as positive in all

cases and was calculated using the following formula (Ghoshal and Sarkar, 2013).

Seed rate deviation, % =

$$\frac{\left[\begin{array}{l}Theoretical\ amount\ of\ seeds\ falling\ in\ 5\ m\ length-\\ Actual\ amount\ of\ seeds\ collected\ in\ 5\ m\ length\end{array}\right]}{\text{Theoretical amount of seeds falling in 5 m length}} \times 100 \quad (3)$$

Seed distribution

The seed distribution was calculated using the following formula (Ghoshal and Sarkar, 2013).

$$S_e = \left[1 - \frac{Y}{d}\right] \times 100 \quad (4)$$

where,

S_e = Seed distribution, %

Y = average numerical deviation of number of seeds per meter length of row from average number seeds per meter run

d = average number of seeds per meter length of row

Seed uniformity test

The drum seeder was operated over grease applied aluminium plate of 50 cm × 300 cm size three times for each combination of speed, wheel diameter and the number of orifices on the drum (Fig. 2). The readings for the seed spacing were recorded for a length of 1 m in each row (Fig. 3). The average value was found out and the coefficient of uniformity was calculated by the following formula (Ghoshal and Sarkar, 2013).

$$\text{Coefficient of uniformity, (\%)} = \left(1 - \frac{\Sigma|X-\bar{X}|}{N\bar{X}}\right) \times 100 \quad (5)$$

where,

Spacing between two consecutive seeds, cm

Theoretical spacing, cm

N = No. of seeds.

Field tests of the manually operated finger millet drum seeder cum fertilizer applicator

The sowing operation was done in a well-tilled field in the experimental farm of the Department of Agronomy, Dr. B.S. Konkan Krishi Vidyapeeth, Dapoli, Maharashtra during the month of April, 2020. The field was divided into 6 sub-plots and was arranged in a 3 × 2 fashion. Each plot was 3.75 × 7 m in size. The plots were sown as per a combination of the independent variables as shown in Fig. 4. The observations of depth and placement of seed in row and number of seeds dropped per m length were noted while plant spacing was recorded on the 20th day after sowing.

Fig. 2. *Sticky plate test in progress*

Fig. 3. *Seed distribution pattern obtained on the sticky belt*

Fig. 4. *Sowing operation on progress*

The performance of the developed drum seeder cum fertilizer applicator for nursery raising was evaluated with the following parameters.

Quantifying the distribution of plant spacing

The plant spacing distribution was quantified using the indices as given in Table 3 (Kachman and Smith, 1995). For the calculations of these indices, the values of theoretical seed spacing were calculated. The quality of feed index is an alternate way of presenting the performance of misses and multiples. The indices determined are tabulated below.

Depth and placement of seed and fertilizer in row

While measuring the depth of the seed placement, the soil covering attachment was kept lifted up so that it could not cover the fertilizer and seeds under the soil. The depth and placement of seeds were measured at five randomly selected points in 1 m travel length leaving initial and final 1 m travel length to avoid the effect of operational error that might have occurred at the beginning and end of the run.

Operating speed

The time required to travel 10 m distance at speeds of 1, 1.5 and 2 km h^{-1} was calculated as 36, 54 and 72 s. The operator was trained to travel 10 m distance in the predetermined time as per the speeds before conducting the actual tests in the field. The time required to travel the distance was measured with the digital watch.

Number of plants m^{-2}

The number of plants at 20 days after sowing (DAS) were measured for 1 m length of eight rows (0.8 m width) leaving initial and final 1 m row length.

Cost of operation

The cost of operation of finger millet drum seeder was calculated by standard method assuming the capital cost of the seeder as ₹ 2000 per unit. The life of the seeder was assumed as 10 years with annual usage as 250 h (Gaikwad, 2010). Operators' wages were assumed as ₹ 300 day^{-1}. The cost of operation includes the fixed and variable costs.

RESULTS AND DISCUSSION

Laboratory tests

Effect of orifice spacing (H), ground wheel diameter (D) and speed (S) on seed rate

The actual seed rate of the seed drill was determined as per the predetermined operating parameters and its levels *i.e.*, number of orifices on the drum (with and without covering belt) as 12 (H_1) and 24 (H_2), diameter of ground wheel as 165 mm (D_1), 230 mm (D_2) and speed of operation, 1.0 (S_1), 1.5 (S_2) and 2.0 (S_3) km h^{-1}. The seed rates obtained using the covering belt on the drums in all cases was always less than with drums without a covering belt. The seed rate was observed to increase with the increase in the forward speed. The seed rate reduced with the increase in the wheel diameter (Fig. 5). The lesser the diameter of the wheel, the higher is its rotational speed and hence that of the seed drum for the same forward speed of the seeder. This resulted in the increase in speed rate with the rotational speed of the drum.

Effect of speed and ground wheel diameter on seed rate deviation

The number of orifices, operating speed, wheel diameter and covering belt played an important role in the seed rate variation. In the drum seeder for finger millet, the seed rate deviation was observed to be reduced with the increase in the peripheral speed of the drum (Fig. 6).

Effect of speed and ground wheel diameter on seed distribution efficiency

In drum seeder, seed distribution efficiency observed to be increased with the increase in the peripheral speed of the drum *i.e.*, decrease in the size of wheel. Seed

Table 3. *Indices for testing the performance of drum seeder*

Indices	Miss index (MISI)	Multiple index (MULI)	Quality of feed index (QFI)
Formula	$I_{miss} = n_1/N$ …(6) where, n1 is number of seed spacing >1.5 Ss, and N is the total number of measured spacing.	$I_{mult} = n_2/N$ …(7) where, n_2 is number of seed spacing ≤0.5 Ss.	$I_q = n_3/N$ …(8) where, n_3 is the number of seed spacing greater than 0.5 Ss and less than 1.5 Ss.

distribution efficiency was always higher when drum was used without belt (Fig. 7).

Effect of speed and ground wheel diameter on number of seeds per meter length of travel

The quantity of seed per meter length of travels was generally observed to be increased with the speed of travel in all cases except with $H_2D_2S_3$ with the belt. This may be due to higher peripheral drum speed, the seeds might not have the chance to fall through orifices. In general, for each of the combinations of the operating parameters, it was observed that the drum with covering belt showed lesser seeds per meter length of travel than without covering belt (Fig. 8).

Effect of speed and ground wheel diameter on seed spacing

The seed spacing was observed to increase with the increasing speed of operation. The drums without a belt showed the higher seed spacing (Fig. 9).

Sticky plate tests

Based on the laboratory results, the trial of the seed drill was conducted on the sticky plate with and without the covering belt and the results are discussed here.

Effect of speed and ground wheel diameter on seed collected

In the sticky belt tests, the number of seeds per meter was measured. It was observed that very few seeds were dropped through both the drums with the covering belt. In the case of the drum with 24 orifices, the quantity of seed drop increased with an increase in the wheel diameter with respect to the forward speed of 1.0 and 1.5 km h^{-1} only. While for all the other speeds and the number of orifices on the drum, the increasing trend of seed drop was observed with respect to the increase in speed and diameter of the ground wheel (Fig. 10).

Effect of speed and ground wheel diameter on average spacing between seeds

The spacing between the seeds was found more for the seed drum with the covering belt. This may be due as fewer seeds were dropped from the drum with a covering belt (Fig. 11).

Effect of speed and ground wheel diameter on uniformity coefficient

It was observed that the uniformity coefficient decreased with the increase in the number of orifices and increase in wheel diameter with and without covering belt (Fig. 12).

Field tests

The sowing operation was done in the experimental farm of the Department of Agronomy, Dr. B.S. Konkan Krishi Vidyapeeth, Dapoli, Maharashtra during April 2020. The performance parameters *i.e.*, depth and placement of seed in row and number of seeds dropped per metre of running length were noted (Table 4). The readings of the seeds were used for the determination of the quality feed index. The observations of the plant spacing were recorded.

Effect of orifices, ground wheel diameter, and operating speed on seed per meter length

The number of seeds per meter length was observed to be increased with an increase in the number of orifices, wheel diameter and the speed of operation (Fig. 13).

Effect of orifice number, ground wheel diameter and operating speed on seedling spacing

The trend of seedling spacing with respect to speed of operation and number of orifices was observed exactly opposite to that of the seed per meter length. None of the reading was observed close to the required seed spacing *i.e.*, 0.45 cm (Fig. 14).

Effect of orifice number, ground wheel diameter, and operating speed on depth of seed placement and fertilizers in row

The depth of operation was observed to increase with the increase in the speed of operation. This might be because the operator holding the drum seeder more firmly with the increase in the speed of operation that in turn increase the weight on the drum seeder. The furrow openers were opening the furrow up to 5 cm depth. However, as the dried and loose soil was free-flowing, some of the soil was falling in the opened furrow before the seeds and fertilizer being dropped. Hence, the fertilizer and seeds were getting placed up to an average depth of 3 cm that is acceptable for finger millet (http://millets.dacfw.nic.in/POP%20Finger.html) (Fig. 15).

Quantifying the distribution of plant spacing

The QFI, MULI and MISI were determined as per Kachman and Smith (1995). It was observed that all the

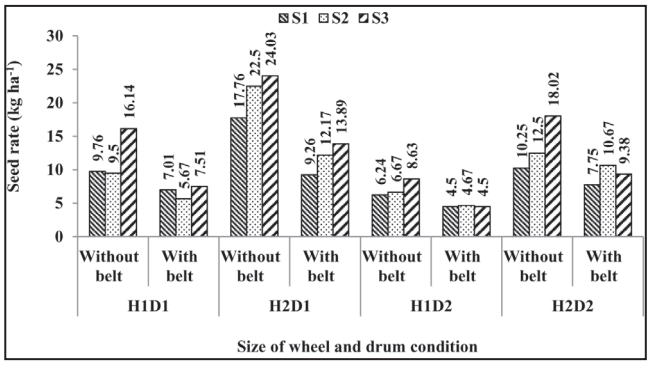

Fig. 5. Effect of speed and ground wheel diameter on seed rate

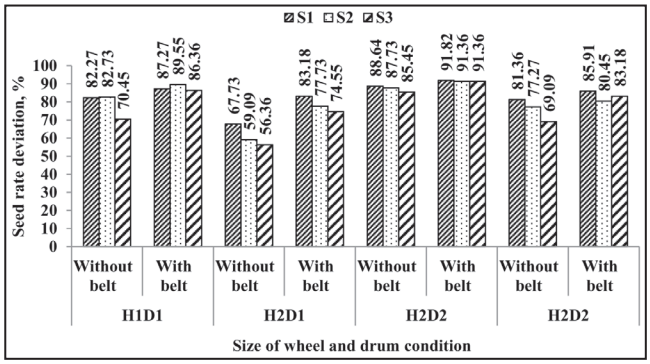

Fig. 6. Effect of speed and ground wheel diameter on seed rate deviation

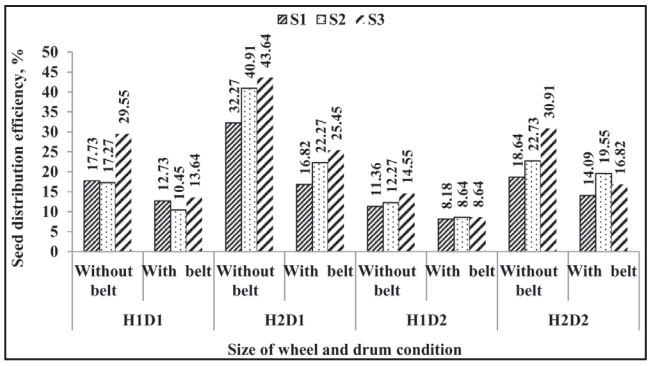

Fig. 7. Effect of speed and ground wheel diameter on seed distribution efficiency

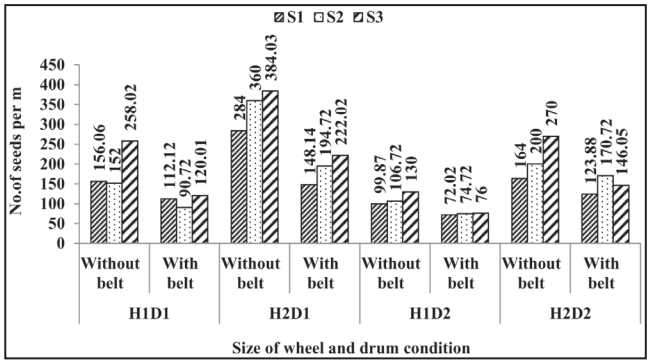

Fig. 8. Effect of speed and ground wheel diameter on seed per meter

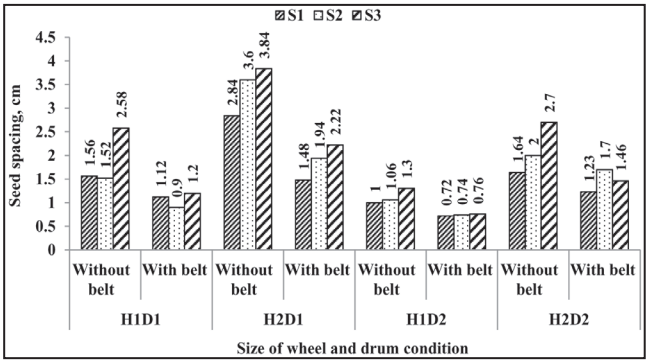

Fig. 9. Effect of wheel size and drum condition on seed spacing

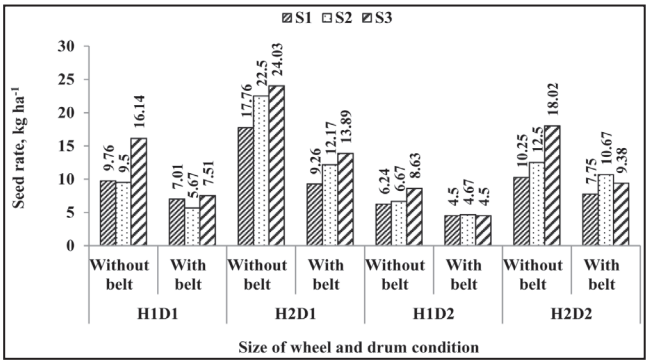

Fig. 10. Effect of speed and ground wheel diameter on seed rate

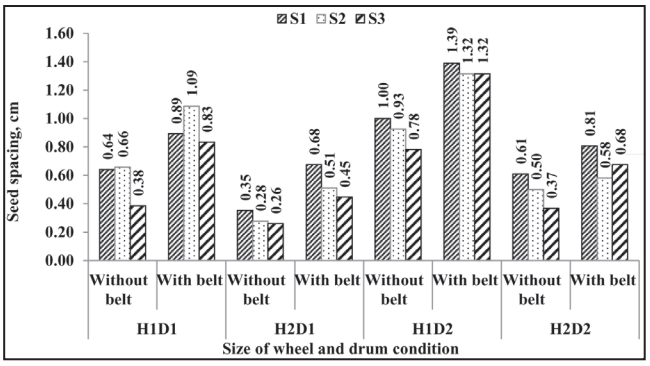

Fig. 11. Effect of speed and ground wheel diameter on seed spacing

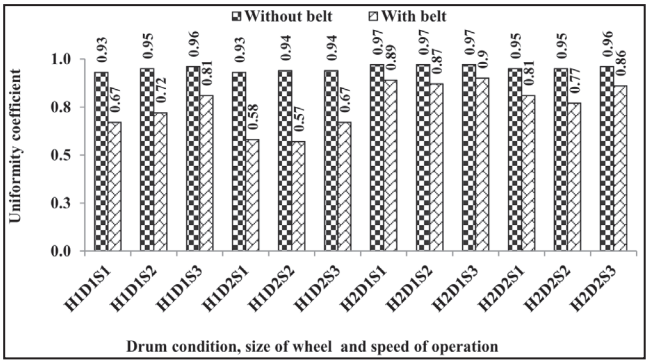

Fig. 12. Effect of drum condition, speed and ground wheel diameter on uniformity coefficient

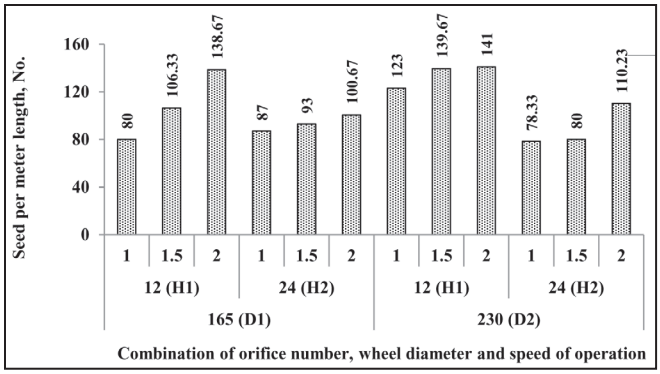

Fig. 13. *Effect of orifice number, ground wheel diameter and operating speed on seed per meter length*

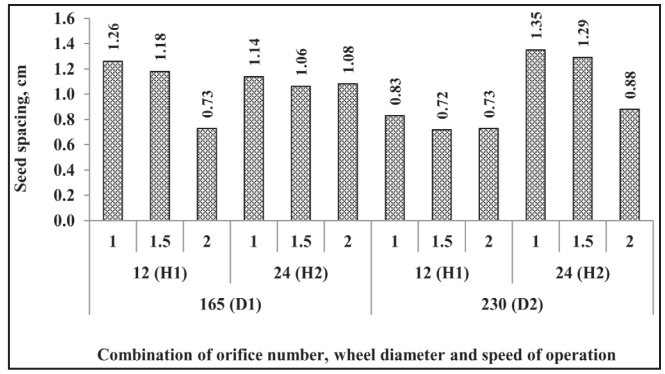

Fig. 14. *Effect of orifice number, ground wheel diameter and operating speed on seed spacing*

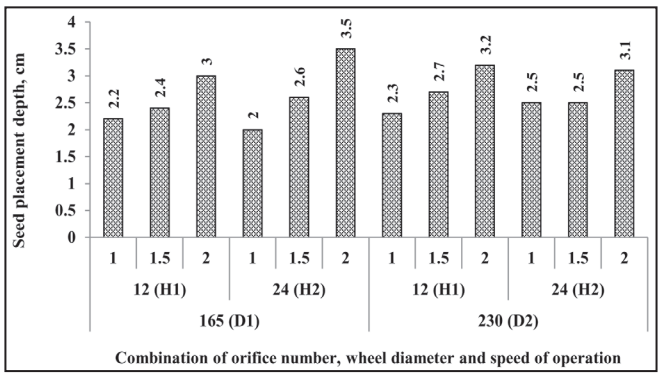

Fig. 15. *Effect of orifice number, ground wheel diameter and operating speed on depth of seed placement*

readings were > 1.5S. No reading was found in QFI and MISI. It indicated that the sowing was done denser than the calculated theoretical value of the seed spacing of the drum seeder.

Effect of operating speed on sowing operation and sowing depth

The drum seeder was operated manually at predetermined speeds for a distance of 10 m. During operation, 1 km h^{-1} speed was observed to be very slow (Table 5). The operator was not able to maintain the line of sowing at this speed. The speeds of 1.5 and 2.0 km h^{-1} were comfortable for the operator, but at 2 km h^{-1} the operator needed to be more cautious to maintain the line

Table 4. *Field tests of manually operated finger millet drum seeder cum fertilizer applicator for nursery raising*

Sl. No.	Ground wheel dia., mm	Number of orifices on drum	Speed, km h^{-1}	QFI* and MISI	MULI*	Seed per meter length, No.	Av. depth of seed placement, cm
1	165 (D_1)	12 (H_1)	1.0	0	100	80	2.2
2			1.5	0	100	106.33	2.4
3			2.0	0	100	138.67	3.0
4		24 (H_2)	1.0	0	100	93	2.0
5			1.5	0	100	87	2.6
6			2.0	0	100	100.67	3.5
7	230 (D_2)	12 (H_1)	1.0	0	100	123	2.3
8			1.5	0	100	139.67	2.7
9			2.0	0	100	141	3.2
10		24 (H_2)	1.0	0	100	78.33	2.5
11			1.5	0	100	80	2.5
12			2.0	0	100	110.23	3.1

*Miss index (MISI), Multiple index (MULI), Quality of feed index (QFI)

of sowing. It was observed that the seed placement was shallow at lower speed. This might be as the soil gets sufficient time to fall in the furrow before the placement of the seed and soil was not sufficiently displaced away from the furrow. At higher speeds, the seeds were getting placed and then it was covered partially with the soil.

Effect of operating parameters on number of plants m^{-2}

The number of plants m^{-2} increased with the increase in the speed of operation and the number of orifices on the drum (Table 6). However, it decreased with an increase in the ground wheel diameter. This may be due to the lesser number of revolutions of the drum to cover the same distance. With the highest number of orifices on the drum, the plant density was very high because the seeds were falling from the orifices on the sidewalls on the drum.

To evaluate the drum seeder in the field, the seed rate of 5 - 6 kg ha^{-1} as per the recommendation by Dr. B.S. Konkan Krishi Vidyapeeth, Dapoli, Maharashtra was considered. The mean value of 5.5 kg ha^{-1} was considered for further calculations. According to the required seed rate and the combination of the number of orifices on the drum and the wheel diameter, the seed rate that could be obtained was determined theoretically.

Cost of operation

The cost of operation of finger millet drum seeder was found to be ₹ 52 h^{-1}. The unit when operated at 1.5 km h^{-1} with 0.4 m width and efficiency of operation as 70%, the cost is calculated as ₹ 963 ha^{-1}.

The developed drum seeder cum fertilizer applicator for finger millet could help in sowing the seeds more uniformly compared to the manual sowing operation. The seed drill operated with a 24 orifice drum at 1.5 km h^{-1} speed using 165 mm diameter wheel and also at 2 km h^{-1} speed using 230 mm diameter wheel was found to be suitable for the sowing of finger millet seeds uniformly for nursery raising to obtain healthy seedling for transplanting. Based on observations, 1.5 km hr^{-1} speed of operation was found comfortable and efficient.

Table 5. *Calibration of manually operated finger millet drum seeder cum fertilizer applicator for nursery raising*

Sl. N.	Wheel dia., mm	Operating speed, km h^{-1}	Ground wheel speed, RPM	Seed collected, g m^{-2}			
				Seed drum with 12 orifices		Seed drum with 24 orifices	
				Without belt	With belt	Without belt	With belt
1	165	1.0	32.15	6.50	4.67	11.83	6.17
		1.5	48.22	9.50	5.67	22.50	12.17
		2.0	64.30	21.50	10.00	32.00	18.50
2	230	1.0	23.06	4.16	3.00	6.83	5.16
		1.5	34.59	6.67	4.67	12.50	10.67
		2.0	46.13	10.83	6.33	22.50	12.17

Table 6. *Plant density obtained by sowing finger millet seeds by developed finger millet drum seeder cum fertilizer applicator for nursery raising*

Sl. No.	Wheel dia., mm	Forward speed, km h^{-1}	No. of plants m^{-2}	
			Seed drum with 12 orifices (H_1)	Seed drum with 24 orifices (H_2)
1	165	1	248	331
		1.5	480	656
		2	899	928
2	230	1	191	290
		1.5	217	315
		2	401	619

CONFLICTS OF INTEREST

The authors declare that there is no conflict of interest.

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