Performance Evaluation of Sponge Pad and Disc Type Seed Metering Mechanism for Finger Millet

Abhishek Kumar*[1]

[1]*Dept. of Agricultural Engineering, Teerthanker Mahaveer University, Moradabad, Uttar Pradesh*

Abstract-Finger millet is an important crop among the small millets and third among millets in the area and production after sorghum and pearl millet in India. It is cultivated as a rainfed crop for its valued food grains and adaptability to a wide range of geographical areas and agro-ecological diversity in India. Finger millet occupies an important place in the agriculture of the Uttarakhand hilly regions. In the state of Uttarakhand, sowing of majorly grown finger millet still rely on broadcasting method. Sowing by broadcasting involves randomly scattering of seeds on the seedbed which results in higher seed rate. Hence a sponge pad and disc type metering mechanism metering were evaluated for two speed ratios levels 1:11 and 1:58. The metering mechanism was tested in laboratory at five speed levels (2,3,4,5 and 6 km h^{-1}) The result revealed that initially there was a slight increase in seed rate with the increased in forward speed from 2 to 3 km h^{-1}. When the forward speed increased from 3 to 4 km h^{-1}, the seed rate was decreased. The maximum and minimum mean seed rate for speed ratio 1:11 was found to be 19.79 kg ha^{-1} at forward speed of 3 km h^{-1} and 18.29 kg ha^{-1} at 4 km h^{-1}, while when the speed reduction ratio reduced from 1:11 to 1:58. The seed rate was also be declined from 19.79 to 14.19 kg ha^{-1} when speed was increased from 3 to 4 km h^{-1}. As the forward speed increased beyond 4 km h^{-1}, the seed rate was started to be declined. The effects of forward speeds on different indices were found insignificantly at 5 % confidence level on seed rate of finger millet while the effects of forward speed on seed spacing and speed ratio on seed rate was significant at 5 % confidence level.

Keywords: Finger millet, metering mechanism, forward speed, speed reduction ratio, power transmission

INTRODUCTION

In India, millets are cultivated from sea level to mid hills i.e. from Tamil Nadu in South to Uttarakhand in North and from Gujarat in the West to Arunachal Pradesh in the East. Finger millet is a more nutritious food than other cereals (Bhandari *et al*., 2005 and Dida MM 2006). Finger Millet improvement mineral nutrient as compared to other major cereals like wheat, rice, and sorghum (Gupta *et al*., 2017 and Sharma *et al*., 2017). Even though, the area cultivated to finger millet using customary method increased by 5.7 % from 2008 to 2011, the research effort was very limited and lacked improved production packages for the production of the crop. Consequently, farmers used the traditional system of production and the yield was limited to 1507 kg ha^{-1} (CSA, 2011) though finger millet has high yield potential of 3000 kg ha^{-1}(Tadesse M., 1995). Row planting in general has many advantageous in contrast to broadcasting. Previous research work on plant population studies on finger millet indicated that most vigorous finger millet was observed when finger millet was planted at 20-30 cm spacing and 10-15 kg ha^{-1} seed rate. Planting finger millet in rows gives the highest grain yield as compared to broadcasting (Shinggu C.P *et al*., 2009 and GRDC, 2011). One of the major constraints of broadcasting in finger millet production in the field is weed management which leads to difficulty in crop management and as such requires high labour input from seed sowing to crop harvesting. Hence, determination of optimum seed rate and inter row spacing for finger millet is one area to be considered for raising productivity and production of finger millet in the region. Hence the present study aimed at determining the most suitable seed rate and row spacing that can give the optimum yield of finger millet in Uttarakhand states. The declining trends have been witnessed due to the replacement of area under millets with rice and wheat. Also, lack of mechanization and unavailability of farm machinery adds drudgery in traditional methods of farming of millets which may further lead to decrease in production. The data explains that the area under finger millet has decreased from 2.51 million hectares during 1960-61 to 1.01 million hectares in 2022-23. In the state of Uttarakhand, sowing of majorly grown finger millet still rely on broadcasting method. Sowing by broadcasting involves randomly scattering of seeds on the seedbed which results in higher seed rate.

Moreover, broadcasted seeds fail to germinate as they remain on the surface of the soil and do not get appropriate moisture. This can be deliberated as one of the reasons for fall of production and area under these millets in the state. The problem can be conquered by the mechanization of farms using improved sowing equipment. The technological interventions in sowing of finger millet will lead to upsurge in production as well as productivity along with timeliness of operations and lessened cost of production. Therefore, there is need of time to develop an appropriate seeding machine with suitable seed metering mechanisms for sowing these small millet seeds in order to help small and marginal farmers in managing their farm operations and increase yield.

MATERIALS AND METHODS

The crop parameters were already studied for designing of the sponge pad and disc type metering mechanism and the soil type, depth of placement and other soil parameters were also considered.

Experimental setup

The performance evaluation of the seed metering devices was carried out in laboratory using sticky- belt method (Fig.1). The sticky- belt test setup was available in the department of Farm Machinery & Power Engineering of Govind Ballabh Pant University of Agriculture and Technology Pantnagar Uttarakhand. It consists of a sticky belt setup, power transmission unit.

Fig.1: Setup of sticky belt conveyor system

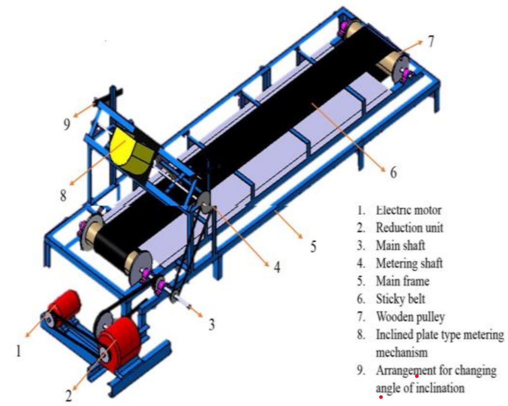

Fig.2: Isometric view of laboratory testing of the developed mechanism

Sticky belt setup

The sticky belt setup model as shown in (Fig. 2 and 3) consists of an endless rubber conveyor belt of 6100 mm in length and 300 mm in width placed over two pulleys. The pulleys are made up of wood having 140 mm diameter and 510 mm length spaced 2.83 m apart.

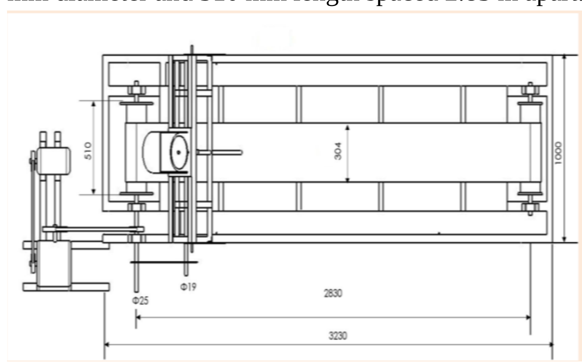

Fig. 3: Top view of belt conveyor system

Power transmission unit

The power transmission to the metering mechanism in two ways as shown in Fig.4. the power delivered first to sticky belt and then sticky belt to metering mechanism respectively. There were two ways of speed ratios viz. 1:11 and 1: 58 at which data were collected. In the Fig. 4 shown the speed ratios and a chain of 1345 mm length and 12.70 mm pitch was used to connect the driver and driven sprockets.

Arrangement -1	Arrangement-2
Speed ratio between metering shaft and drive wheel was kept as 1:11.	Speed ratio between metering shaft and drive wheel was kept as 1:58.

Fig.4 Speed ratio arrangement between metering shaft and drive wheel

Power transmission to sticky belt

The belt conveyor was operated by power transmission unit consisting of an electric motor, a reduction gearbox and V-belt pulley arrangement. Single phase 1.5 kW electric motor running at 1440 rpm transmits power to a reduction unit having worm gear with a speed reduction ratio of 20:1 through V-belt and pulleys of 101.6 cm. A single phase starter was used to start and cut off the power supply to the electric motor. Further, the power was transmitted from reduction unit through V-belt and pulley arrangement to main shaft of 25 mm diameter on which the conveyor belt was mounted. The speed of the conveyor belt was varied according to the forward speed requirements by using V- pulleys of different sizes as described in Table 1. According to the forward speed requirements different sizes of the pulleys were decided based on following calculations:

Design Calculation

Forward speed = 2 km h^{-1} = 0.55 $m.s^{-1}$,

Outer diameter of wooden pulley (D) = Diameter of wooden pulley + belt thickness

= 14 cm + 0.8 cm = 14.8 cm = 0.148 m

Peripheral speed of main pulley (m/s) = $V = \frac{\pi D_m N}{60}$ (1)

where,

D_m = diameter of main pulley, m; and

N = speed of the main pulley, rpm

At 2 km h^{-1} forward speed, V = 0.55 m s^{-1}

From the equation (1) N_m can be calculated as:

$N_m = \frac{(Vx60)}{\pi D_m}$

= (0.55x60)/0.148π = 71.01 rpm ≈ 71 rpm

From above calculations, it is clear that speed of the pulley should be 71 rpm in order to attain forward speed of 2 km h^{-1}.

Calculation of Size of the Pulley

Size of the pulley can be decided from the following methods.

Speed of the electric motor = N_1 = 1440 rpm

Speed reduction ratio between electric motor and reduction unit = 1:1

Speed at the input shaft of the reduction unit = N_2 = 1440 rpm

Speed reduction ratio of reduction unit = 20:1

Speed at the output shaft of the reduction unit = N_3 = N_2/20 = 1440/20 = 72

The output shaft of the reduction unit give drive to the main shaft on which wooden pulley is mounted through V-belt and pulley. The size of pulley can be decided from the following calculations as:

Size of the pulley at output shaft of reduction unit (diameter of pulley) =D_1 = 10 inches = 254 mm.

So, the size of pulley at the main shaft can be given by following equation,

$N_3/N_m = D_m/D_1$

$D_m = (N_3 x D_1)/N_m$

D_m = (10x72)/71 = 10.14 in ≈ 10 inches. = 25.4 cm=254 mm

(ii) Power transmission to metering unit

The shaft of the metering unit having 19 mm diameter gets drive through chain and sprocket arrangement from the main shaft. The sprocket on the main shaft has 15 teeth's and was operated by power transmission unit consisting of an electric motor, a reduction gearbox and V-belt pulley arrangement. Three phase 1.5 kW electric motor running at 1440 rpm transmits power to a reduction unit having worm gear with variable speed reduction ratio through V-belt and pulley of 101.6 cm. A three-phase starter is used to start and cut off the power supply to the electric motor. The power is transmitted to the main shaft of 25 mm diameter which gives drive to the sprocket assembly and thereby to the metering shaft.

Table 1: Details of the power transmission unit

Type of power transmission	Speed reduction ratio	Parameters	Size of the elements			
			Shaft diameter	Pulley/sprocket size	Belt/ chain size	Speed attained, rpm
Electric motor to reduction gearbox						
V belt and pulley	1:1	Electric motor:	25 mm	101.6 mm	52 B	1440
		Reduction Gearbox:	30 mm	101.6 mm		1440
Reduction gearbox						
Worm gear Drive	20:1	Input shaft:	30 mm			1440
		Output shaft:	43 mm			72
Reduction gearbox to main shaft of conveyor belt						
V belt and Pulley	According to speed requirement	Reduction Gearbox:	43 mm	10 inches		72
		Main shaft: Forward speed: 2 km h^{-1} 3 km h^{-1} 4 km h^{-1} 5 km h^{-1} 6 km h^{-1}	25 mm	254 mm 203.2 mm 152.4 mm 127 mm 101.6 mm	69 B 69 B 64 B 64 B 64 B	72 108 144 177 215

Sponge pad and disc type seed metering mechanism

The seed metering mechanism consists of a disc of diameter 125 mm with thickness as 1.0 mm as shown in Fig.5. One side of this plate, a light density sponge (density 23 kg m^{-3}) circular in shape was glued. The disc was placed on a square rod of 10 mm size. The sponge disc was kept in contact with this side of the seed hopper. A spring was used to keep the disc in close contact with delivery side of casting. The seeds were carried out between the groove casting and the sponge pad when rotated through the square metering shaft. The seeds were released at a point where there is an opening in the grooved side of hopper above the delivery funnel.

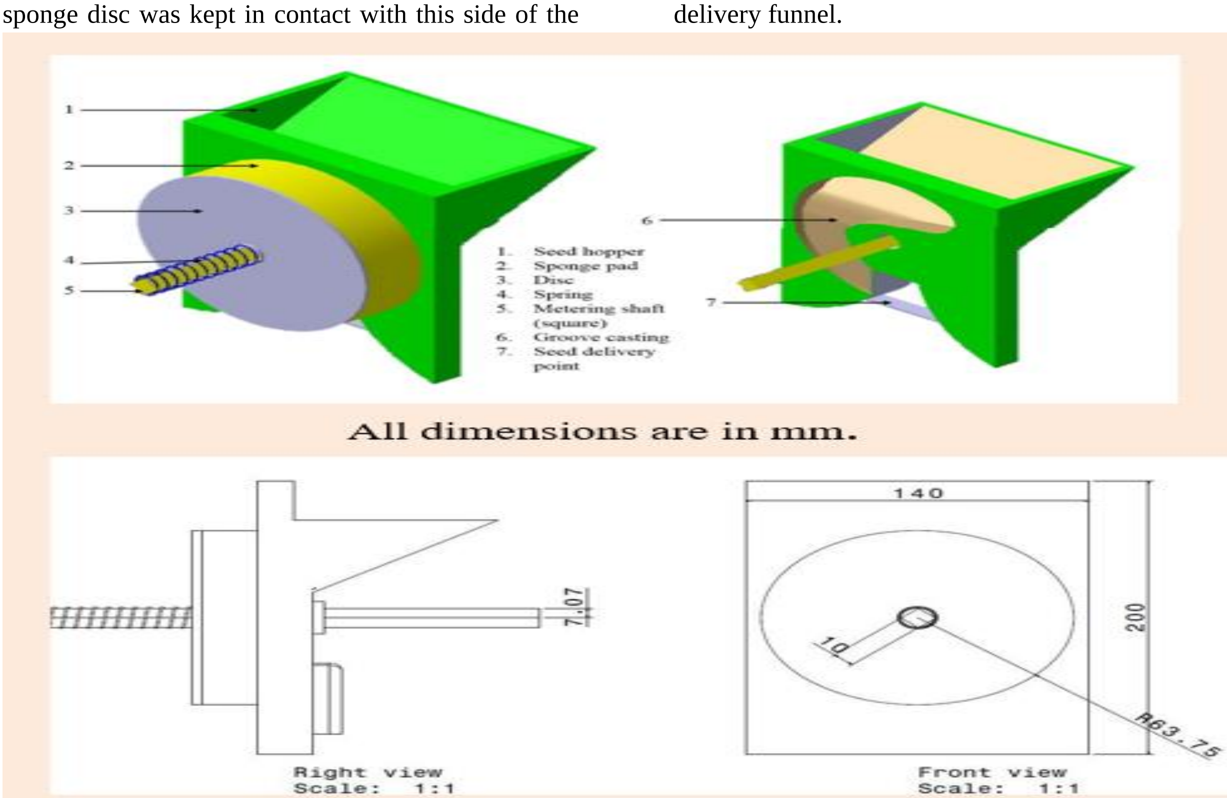

Fig 5. Side view and front view of metering mechanism

Table 2: Experimental parameters

S. No.	Particulars	Levels
i	Experimental variable Speed of operation	5 (2,3,4,5 and 6 km h^{-1})
ii	Performance indicator (a) Seed rate, kg ha^{-1} (b) Mean seed spacing, cm	
iii	Replication	10 (for seed rate) 3 (for mean seed spacing)
iv	Theoretical seed rate requirement, kg ha^{-1}	10-15 kg ha^{-1}

Calibration of the metering mechanism

For determination of seed rate

To know the quantity of seeds sown per unit area, seed rate was calculated during laboratory testing. The procedure followed to calculate the seed rate is as follows:

Step 1: The effective (nominal) width (metres) of the seed drill was calculated by multiplying the number of furrow openers (say n) taken and the spacing (say s) between two adjacent furrow openers. W = n x s, metre.

Step 2: The diameter of the drive (lug) wheel was measured, say D metre.

Step 3: The circumference of the drive wheel i.e. πD metre was determined.

Step 4: Then, the area covered (A) by the seed drill in one revolution of the drive wheel as

$$A = W \times \pi D, \text{ sq metre.}$$

Step 5: The number of revolutions N_r were determined to cover one ha area as $N_r = 10{,}000/A$.

Step 6: The number of revolutions were recalculated after allowing 10 percent wheel slippage as ($N_r - 0.1N_r$). The answer is rounded off to whole number.

Step 7: Then the lug wheel was driven at different speeds (2, 3, 4, 5, 6 km h^{-1}) with the help of 3 phase motor assembly. The ratio of speeds between drive wheel and metering shaft is kept constant at all the speeds.

Step 8: Polythene bags to each seed tube were tied.

Step 9: The seed box was filled with finger millet seeds.

Step 10: At ten revolutions of the metering shaft, the seeds dropped from each tube were collected.

Step 11: The seeds dropped were weighed, say Z kg.

Step 12: The required seed rate in kg ha^{-1} is calculated as:

In 10 revolution of metering shaft, the seed dropped = Z kg.

Say the speed ratio between drive wheel and metering shaft is *y*,

Then in 10*y* revolutions of drive wheel the seeds dropped = Z kg

Therefore, the same in one revolution = $Z/10y$

Hence, in N_r revolutions of developed machine it would be = $(Z/10y) \times N_r$.

For mean seed spacing

The performance evaluation of seed metering mechanism was carried out according to the procedure mentioned in the Indian Standard Code IS 6316: (1993). Seeds were filled in the prototype model of seed hopper. The distance between the tube and sticky belt was kept minimum to avoid bouncing of seeds delivered from the tube on sticky belt. Grease was applied to the belt so that delivered seeds get stuck on the belt. The conveyor belt was operated at the desired speed by changing pulleys of different sizes. The setup was operated by an electric motor as shown in Fig.6 and the seeds were allowed to fall on the portion of the belt on which grease was applied. Thereafter, the distance between the seeds was measured. For each metering mechanism at each speed, three replications were taken to get the average value for each combination of treatments. The seed to seed spacing was measured with the help of scale for each test run. Three replications were taken at each speed for the metering mechanism and the average value of the seed spacing was calculated using Equation given below. For this purpose, the Christiansen's Uniformity Coefficient was used for calculating the uniformity of distribution pattern of finger millet seeds at different forward speed is described below.

Fig 6. Measurement of distance between seed drop from prototype model by measuring tape

$$CU = \left(1 - \frac{\sum|X - \bar{X}|}{n\bar{X}}\right) \times 100$$

Where,

CU = christiansen's coefficient of uniformity, %

X = seed to seed spacing, cm

$\bar{X}$ = average spacing between seeds, cm

n = total no of seeds collected

RESULTS AND DISCUSSIONS

Effect of forward speed on seed rate for 1:11 speed ratio

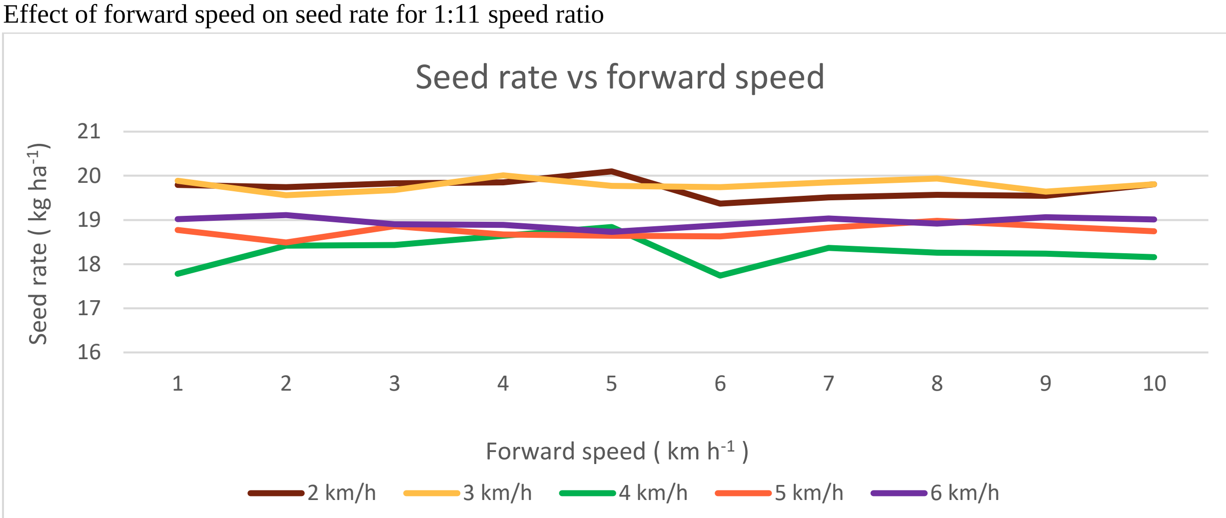

Fig 7. Effect of forward speed and speed ratio (1:11) on seed rate of finger millet

The above graph in Fig.7 revealed that initially there was a slight increase in seed rate with the increase in forward speed from 2 to 3 km h^{-1}. When the forward speed increased from 3 to 4 km h^{-1}, the seed rate was decreased while during forward speed of 4 to 6 km h^{-1}, the maximum and minimum mean seed rate at speed ratio 1:11 was found to be 19.79 kg ha^{-1} at forward speed of 3 km h^{-1} and 18.29 kg ha^{-1} at 4 km h^{-1} forward speed.

Effect of forward speed on seed rate for 1:58 speed ratio.

From the graph the result revealed that the as the speed ratio decreased from 1:11 to 1:58. The seed rate was also be declined from 19.79 to 14.19 kg ha^{-1} when speed was increased from 3 to 4 km h^{-1} respectively. As the forward speed increased beyond 4 km h^{-1}. the seed rate was started to be declined as shown in Fig.8.

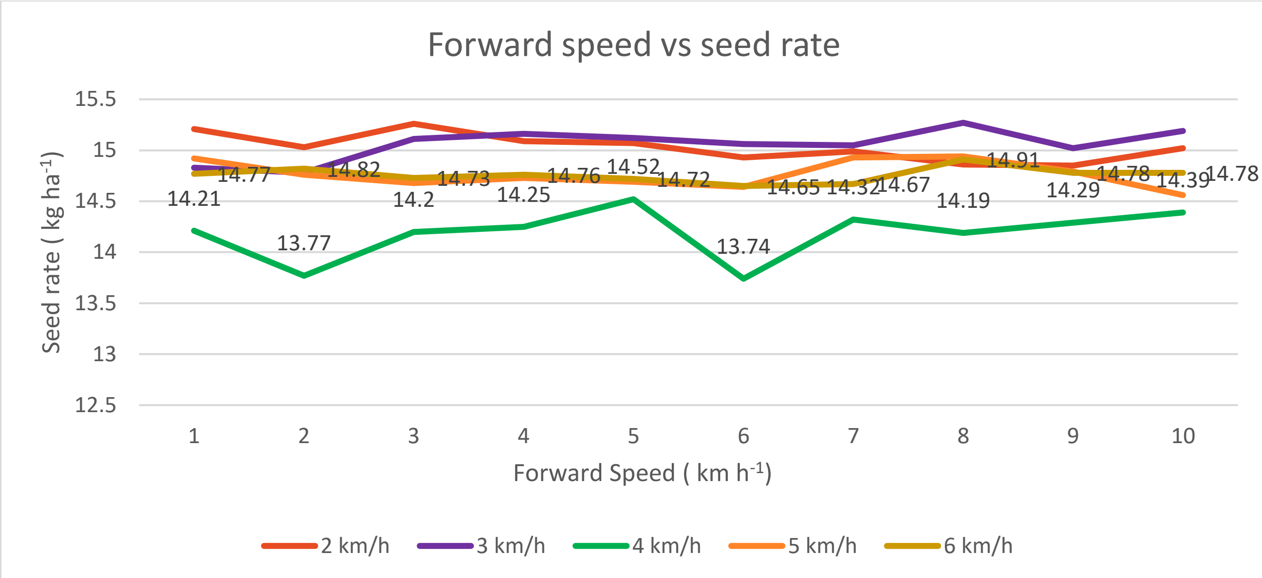

Fig. 8. Effect of forward speed and speed ratio (1:58) on seed rate of finger millet

Table 3: Calibration data of metering mechanism at different forward speeds

Speed (km h^{-1})	2			3			4			5			6		
	Seed rate (kg ha^{-1})														
Replication	FO-1	FO-2	Mean	FO-1	FO-2	Mean	FO-1	FO-2	Mean	FO-1	FO-2	Mean	FO-1	FO-2	Mean
Speed ratio	1:11	1:58		1:11	1:58		1:11	1:58		1:11	1:58		1:11	1:58	
1	19.79	15.21	17.53	19.89	14.83	17.36	17.78	14.21	15.50	18.77	14.92	16.84	19.02	14.77	16.89
2	19.74	15.03	17.38	19.56	14.78	17.21	18.42	13.77	15.66	18.49	14.76	16.62	19.11	14.82	16.69
3	19.83	15.26	17.55	19.68	15.11	17.40	18.43	14.20	15.89	18.86	14.68	16.77	18.9	14.73	16.85
4	19.85	15.09	17.47	20.01	15.16	17.58	18.64	14.25	16.01	18.67	14.73	16.72	18.89	14.76	16.83
5	20.10	15.07	17.56	19.77	15.12	17.44	18.84	14.52	16.23	18.64	14.69	16.67	18.73	14.72	16.73
6	19.37	14.93	17.15	19.74	15.06	17.40	17.74	13.74	15.32	18.63	14.64	16.64	18.88	14.65	16.76
7	19.51	14.99	17.25	19.85	15.05	17.45	18.37	14.32	15.91	18.82	14.93	16.87	19.03	14.67	16.85
8	19.57	14.86	17.22	19.94	15.27	17.60	18.26	14.19	15.80	18.98	14.94	16.96	18.92	14.91	16.91
9	19.55	14.85	17.20	19.64	15.02	17.33	18.24	14.29	15.83	18.86	14.79	16.87	19.06	14.78	16.91
10	19.81	15.02	17.41	19.81	15.19	17.50	18.16	14.39	15.84	18.74	14.56	16.65	19.01	14.78	16.9
Mean	19.71	15.03	17.37	19.79	15.06	17.43	18.29	14.19	15.80	18.75	14.76	16.76	18.96	15.06	16.83

(FO- Furrow opener)

Effect of forward speed on mean seed spacing for speed ratio

The average value of mean seed spacing for finger millet ranged from minimum of 5.22 cm to maximum of 7.91 cm at forward speed of 2 km h^{-1} and 6 km h^{-1} respectively. The relationship between the mean seed spacing and forward speed for speed ratio is shown in the graph below. The result indicates that the mean seed spacing was increased with the increase in forward speed. The variation in mean seed spacing obtained at various forward speeds from average mean spacing was observed as 1.15 cm.

Table 4: Effect of forward speed on seed spacing

Forward Speed, km.h^{-1}	Mean seed spacing, cm			Mean
	Replication-1	Replication-2	Replication-3	
2	5.15	5.27	5.23	5.22
3	6.10	5.53	5.44	5.68
4	6.98	7.46	7.3	7.24
5	7.75	8.04	7.62	7.80
6	7.96	7.69	8.08	7.91
Mean	6.78	6.80	6.73	6.77

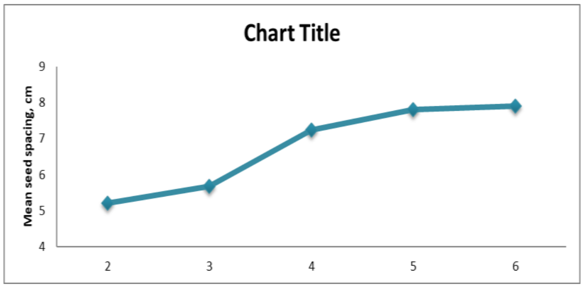

Fig. 9. Relationship between forward speed and mean seed spacing for sponge metering mechanism

Statistical analysis of data

The data was statistical analyzed and it was found that the effect of speed ratio was significant on the seed rate of metering mechanism at the 5 % level of confidence. But the effect of forward speed is non-significant on the seed rate of metering mechanism at 5 % level of significance. From the table 6 it was pertained from the result that the effect of forward speed of seed drill machine on dropping was significant at 5 % level of significance.

Table 5: ANOVA of effect of speed ratio on seed rate.

Source of Variation	SS	df	MS	F	P-value	F crit
Speed ratio	45.796	1	45.796	587.6933	1.72E-05	7.708647
Speed	1.8945	4	0.473625	6.07796	0.054243	6.388233
Error	0.3117	4	0.077925			
Total	48.0022	9				

Table 6: ANOVA of effect of forward speed on seed dropping spacing

Source of Variation	SS	df	MS	F	P-value	F crit
Forward speed	18.52133	4	4.630333	68.14993	3.23E-06	3.837853
Treatment	0.011853	2	0.005927	0.08723	0.917326	4.45897
Error	0.543547	8	0.067943			
Total	19.07673	14				

CONCLUSION

The following conclusions were drawn from the results of this study. The mean maximum and minimum seed rate arrangement-1 (speed ratio 1:11) was 17.43 kg ha^{-1} at forward speed of 3 km h^{-1}. At this speed ratio, the mean seed spacing obtained was zero. The mean maximum and minimum seed rate for arrangement-2 (speed ratio 1:58) was found to be 3.34 kg ha^{-1} and 3.29 kg ha^{-1} at forward speed of 3 km h^{-1} and 6 km h^{-1} respectively. At this speed ratio, the average value of mean seed spacing ranged from minimum of 5.22 cm to maximum of 7.91 cm at forward speed of 2 km h^{-1} and 6 km h^{-1} respectively. The variation in seed rate due to various levels of forward speed was found to be less than 1%.The data showed that the effect of speed ratio on seed rate was significant at 5 % level of significance but the effect of forward speed is not so much on the seed rate of finger millet mechanism and it was found to be insignificant. It was pertained from the result that the effect of forward speed of developed machine on dropping was significant at 5 % level of significance. Based on the experimental result, it can be concluded that the sponge pad and disc type metering device was able to deliver seed rate in the required range of 15-19 kg ha^{-1} However, the mean seed spacing obtained at various speed levels was found closer (6.77 cm) than the required seed spacing of 10 cm.

REFERENCE

[1] Bhandari B, Gawali S, Baral KP, Chowin KR and Rijal DK.2005. Promoting The Utilization of Finger Millet and Its Products Through Public Awareness Activities In Kaski, Nepal. Proceeding of Progree Review Workshopon Finger Millet Under IFAD-NUS Project. Nepal Component, NARC and LiBird.

[2] CSA (Central Statistical Agency). 2012. Agricultural Sample survey 2011-12 volume I. Report on area and production of major crops. Statistical bulletin. May, 2012 Addis Ababa.

[3] Dida MM and Devos K.M.2006. Finger Millet. In genome mapping and molecular breeding in plants cereals and millets berg.pp.333-343. C.kole (Vol 1). Pringer- Verlag, Berlin Heidel.

[4] Goron T.L and Raizada M.N.2015. Genetic diversity and genomic resources available for the small millet crops to accelerate a new green revolution. Journal of Plant Sciences. 77(2)*:* 66-68.
[5] (GDRC)Grain Research and Development Cooperation. 2011.Crop placement and row spacing fact sheet, Blackball Street, Barton. Accessed in, October 2011.www.coretext.com.au.
[6] Gupta S. M, Arora S, Mirza N, Pande A, Lata C and Puranik S. 2017. Finger millet: a “certain” crop for an “uncertain” future and a solution to food insecurity and hidden hunger under stressful environments. Front. Plant Science. https://doi.org/10.3389/fpls.2017.00643.
[7] Shinggu, C.P, Dadari S.A, Shebayan J.A, Adekpe D.I, Mahadi M.A, Mukhtar A.A and Sala S.W.2009. Influence of spacing and seed rate of weed suppression in finger millet(Eleucine carocana gaertn). Middle- East Journal of Scientific Research 4(4) : 267-270.
[8] Sharma D, Jamra G, Singh U.M, Sood S and Kumar A. 2017. Calcium biofortification: Three pronged molecular approaches for dissecting complex trait of calcium nutrition in finger millet (Eleusine coracana) for devising strategies of enrichment of food crops. Front. Plant Sci. https://doi.org/10.3389/fpls.2016.02028.
[9] Tadesse M. 2015.Finger millet: A potential crop in Ethiopia. In: Samwiri Z, and Ejeta G.(eds.). Sorghum and Millet Research in Eastern and Central Africa. Proceeding of a workshop organized to reestablished sorghum and millet research networks in the region. 6-9 Nvember Kampala, Uganda, 1995.