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Development of Manually Operated Single Row Millet Planter cum Fertilizer Drill

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ABSTRACT: An investigation was carried out for identification of slot size on vertical plate type metering device and development of single row millet planter-cum-fertilizer drill for *kodo* (*Paspalum scrobiculatum*) and *little millet (panicum sumatrense)*. Experiments were conducted in laboratory with three slot sizes and three forward speeds (1, 2 and 3 km/h) with *kodo* and little millets. Slot size of 3 x 3 mm was found to be suitable for *kodo* millet as it delivered optimum average seed spacing (ASS), seed rate (SR) and coefficient of uniformity (U_c) as 5.90 cm, 4.50 kg/ha and 0.90, respectively. For little millet also, 3 x 3 mm slot size on vertical rotor plate provided optimum ASS, SR and U_c as 5.70 cm, 2.24 kg/ha and 0.82, respectively. No seed damages were observed with any of the selected plates. Vertical plate with 10 × 10 mm slot size at 40% opening of shutter was found suitable for fertilizer metering for both crops. Based on the laboratory evaluation, a manually operated single row planter-cum-fertilizer drill was developed and evaluated under field conditions. The implement field capacity and field efficiency was found to be 0.048 ha/h and 69% for *kodo* and 0.05 ha/h and 68% for little millet, respectively. Seed saving with developed planter-cum-fertilizer drill as compared to traditional method of line sowing and broadcasting was found to be 76% and 90%, respectively for *kodo*; for *little millet*, it was 83% and 93% respectively. The cost of operation was found to be ₹ 750/ha for *kodo* and ₹ 662/ha for little millets. Yield obtained with developed planter-cum-fertilizer drill were 1870 kg/ha and 1560 kg/ha which was to 139% and 51% more when compared with broadcasted *kodo* and *little millet* respectively.

Key words: Coefficient of uniformity, metering device, millet, planter-cum-fertilizer drill

Introduction

Millets are one of the oldest cultivated food crops known to humans (Kiple, 2001). They are highly nutritive grains compared to fine cereals. World's millet production is 30.72 Mt from cultivated area about 30.11 Mha (FAO, 2015). India is the leading country in the world with production, area under cultivation and yield of 11.42 Mt, 8.9 Mha and 1283 kg/ha, respectively. Millets are grown in diverse soils, varying rainfall regimes and in areas widely differing in thermo and photoperiods. The resilience exhibited by these crops is helpful in adjusting themselves to different kinds of ecological niches because of their eco-friendly nature. All these have made them quite indispensable to rainfed, tribal and hill agriculture where crop substitution is difficult (Michaelraj and Shanmugam, 2013). Despite having various advantages, total area harvested is declining from few decades. It may be due to the lower cost of the produce, area under cultivation and lower level of mechanization in all production operations (Sims *et al.,* 2016).

In India, millets are sown by broadcasting and drilling by *tifan* or traditional implements. The use of such devices results in non uniform distribution of seeds which in turn gave excess plant population and uneven spacing's. Non uniformity in seed spacing and plant population resulted in reduced crop yield (Norris, 1988). Uniformity of seed spacing is an important factor in designing the seed metering device. Besides the design of metering device, there are other operational parameters that affect the precision distribution of seeds. The seed metering device may not singulate seeds and sometimes results in large spacing between plants and overcrowded plants (Parish *et al*., 1991). Broadcasting and drilling methods hinder in intercultural operations and effective weed control. Further, harvesting and threshing operations become more effective if sowing is done in line rather than broadcasting (Khan and Sahrigi, 1990). Since millets grain size is small, it is very difficult to singulate seeds and obtain uniform spacing in rows without much scattering with commonly employed metering device used in seed drill such as fluted roller. The fluted roller type device is not suitable for metering small seed like millets in general and *kodo* and little millet in particular due to smaller in size and easily subjected to mechanical damages. Commonly used metering devices in the planters are vertical plate, inclined plate and horizontal plate with cells/cups/slots over the periphery etc. Shafy (1986) found that using seed drill for sowing onion seed gave high production than other sowing methods i.e. manual seed broadcasting, manual sowing in rows, self-propelled machine. Agdag *et al*. (2001) reported that row spacing affects grain yield and other agronomic characters of millet. Further poor seed germination may cause undesirable misses in field. Different types of seed metering devices have been employed aiming precision sowing of small seeds. The first precision planters developed were horizontal plate planters with cells on the periphery. Although, horizontal seed metering mechanism places seed precisely when compared with other mechanisms, but setting and fabrication of the unit is costlier. Inclined plate seed metering device consists of a metering plate with cells on its periphery to carry one seed in each cell at appropriate time from hopper to the furrow through a seed tube (Kepner *et al.,* 1978). Later precision planters had vacuum system for metering of seeds, but these planters cost more than mechanical planters. Ahmed and Gupta (1994) developed a manually operated electrostatic planter for small seed and reported that there was no damage to seeds passing through metering device, but number of seeds picked up by electrostatic charge varied from 2-6 seed per hill. Vertical plate type metering device is now being used in most of the planters, but for small seeds at higher speed of operation and improper maintenance of clearance between the plate and surface, the seeds may get damaged. However, vertical plate type seed metering device has no friction surface, hence no damage for small seeds. Therefore, an attempt was made to identify the suitable size of slot on vertical plate type metering device for sowing of millet seeds. This work directed to determine some of the physical properties of common varieties of millet seeds, to develop a vertical plate type metering device and to study of the metering device in laboratory and field conditions.

Materials and Methods

Physical properties of seeds and slot sizes

The physical dimensions of *kodo* millet and little millet were measured for designing the size of slot on seed metering device. Therefore, the seeds of popular varieties of selected crops were collected and physical properties such as length, breadth, eccentricity, area, equivalent diameter and thousand grain weights were determined. The slot sizes and its configuration on metering plate were shown in Figure 1. Metering plates were fabricated from aluminium, as it is light in weight, corrosion resistant and easy to fine finishing using fabrication machines. The metering devise was vertical plate with slot size 3 × 3 mm (diameter (D) × width (W)) for seed metering. Similarly, for fertilizer metering, vertical plate with slot size 10 × 10 mm (D × W) was selected considering the fertilizer requirement as 100 kg/ha DAP for selected millets. Number of slots on the periphery of both seed and fertilizer metering plates were 24 and the diameter of the seed and fertilizer metering plates were kept as 120 mm.

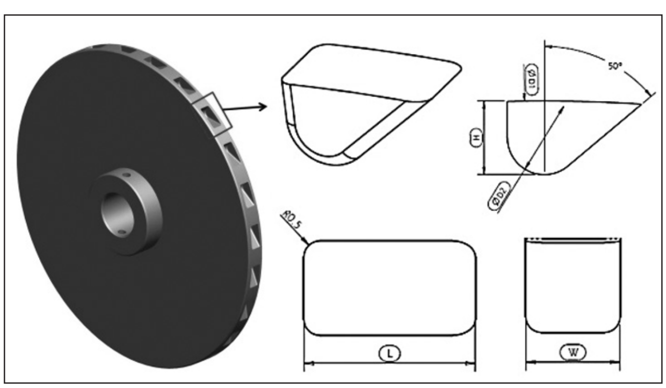

Fig. 1 : Slot sizes and their configuration for vertical seed metering plate

Development of laboratory setup

The metering plates were tested for functional performance by conducting experiments under laboratory conditions using a sticky belt apparatus. The vertical plate type seed metering device was installed on the sticky belt setup (Figure 2) using appropriate accessories and fixers that are used in final proto type development. Respective metering device was fixed in seed box and filled with seeds of *kodo* and little millets for each experiment. Grease was spread on the belt for a length of 8 m and test runs were carried. The setup was operated at different speeds (1 to 3 km/h) and data on seed to seed spacing and number of seeds at each spacing for 8 m belt run was recorded. Three replications were taken for each speed and slot size for *kodo* and little millet.

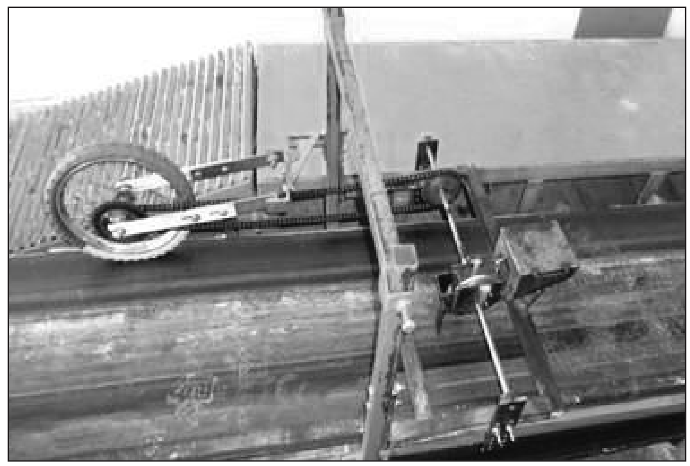

Fig. 2 : Developed laboratory setup of vertical plate type on sticky belt

The selection range of speed of operation and sizes of slots was decided based on size of seed and source of power. Three levels of slot sizes, viz. 3 × 2.5 mm (MS_1), 3 × 3 mm (MS_2) and 3 × 4 mm (MS_3) and three forward speeds 1, 2 and 3 km/h were taken as independent variables. Average seed spacing (ASS) (cm), seed rate (SR) (kg/ha) and coefficient of uniformity (U_c) were determined using the following formulae.

$$\text{Average seed to seed spacing, cm} = \frac{\text{sum of spacings}}{\text{total number of spacing}}$$

$$\text{Seed rate, kg/ha} = \frac{\text{total number of seeds delivered in 8 m run length} \times \text{1000 seed weight, kg} \times 10}{\text{run length, m} \times \text{desired row to row spacing, m}}$$

Coefficient of uniformity

The new method of coefficient of uniformity (U_c) was developed for seed spacing evaluation based on least absolute deviations (Neter *et al.,* 1990). To determine the CV, the number of seeds in a given length on the greased belt was counted in a way similar to that described above for the U_c.

Average number of seed per frame is defined as

$$Spf = \frac{Ts}{Fn}$$

where, T_s = Total number of seeds in each four meter section in each run; F_n = Number of frames on greased belt surface in each run and S_{pf} = Average number of seeds in each frame

A dimensionless quantity, named the frame coefficient was defined as follows

$$Fc = 1 - \left|\left(\frac{Sf}{Spf}\right) - 1\right|$$

$$(F_c = 0 \text{ if } S_f > 2S_{pf})$$

where, F_c = Frame coefficient and S_f = Number of seeds collected in the considered frame

The average of the frame coefficients was then defined as the coefficient of uniformity, Uc and used as a criterion for comparing different seed metering devices. When the value of the Uc approaches one, the metering unit performance approaches perfection.

$$Uc = \frac{1}{n\sum_{i=1}^{n} \mathrm{Fc_i}}$$

where, U_c: Coefficient of uniformity and Fc_i: Frame coefficient

Results and Discussion

Physical properties of seeds and slot sizes

The maximum, minimum and standard deviation of the linear parameters of seed was determined and presented in Table 1. Considering the values obtained for length, breadth and equivalent diameters, three sizes of slots on plates designated as MS_1, MS_2 and MS_3 were fabricated.

Table 1 : Physical properties of *kodo* and little millet seeds

Crop		Area, mm²	Length, mm	Breadth, mm	Eccent-ricity	Equiv. Dia., mm	Roundness	Thousand grain weight, g
Kodo	Avg	5.80	3.08	2.45	0.58	2.71	0.77	4.20
	Max	8.52	3.70	3.10	0.74	3.30	0.96	
	Min	4.68	2.60	2.10	0.22	2.40	0.65	
	SD*	0.70	0.21	0.23	0.12	0.16	0.07	
Little	Avg	3.18	2.51	1.71	0.70	2.00	0.64	2.20
millet	Max	3.86	2.80	2.00	0.86	2.20	0.87	
	Min	2.30	2.20	1.20	0.55	1.70	0.50	
	*SD	0.32	0.14	0.16	0.08	0.10	0.08	

*SD: Standard deviation

Effect of forward speed on different performance parameters of *kodo* millet

Performance parameters such as average seed spacing (ASS), seed rate (SR) and coefficient of uniformity (U_c) for *kodo* millet for three different slot sizes were given in Figure 3a, b and c. The major agronomical requirements for the selected crops i.e. *kodo* and little millets are seed spacing of 5-7.5 cm and seed rate of 3-4 kg/ha, as it was based on the calculations of seed to seed spacing in the range of 7.5 cm and row to row 30 cm spacing and grain weight to maintain the required population by dropping two seeds at time. The average seed spacing (ASS), seed rate (SR) and coefficient of uniformity (U_c) for *kodo* millet for MS_1 at forward speed of 1, 2 and 3 km/h were observed to be 40.91 cm, 0.37 kg/ha, 0.67; 55.79 cm, 0.29 kg/h, 0.63 and 114.36 cm, 0.13 kg/ha, 0.25, respectively. The U_c and SR was decreased with increase in forward speed of operation whereas ASS was increased.

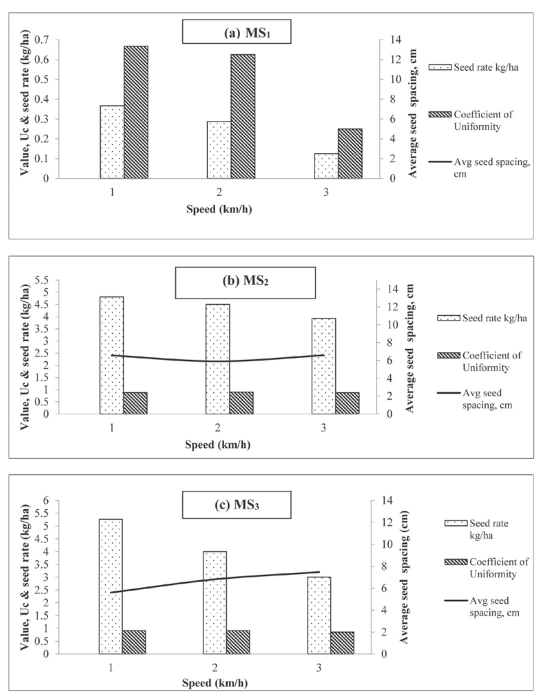

Fig. 3 : Performance parameters for MS1, MS2 and MS3 for kodo millet

However, considering the agronomical requirements of the crop such as seed spacing (5-7.5 cm) and seed rate (3-5 kg/ha), this plate was not found suitable for *kodo* millet. Whereas, performance parameters i.e. ASS, SR and Uc for *kodo* with MS_2 at forward speed of 1, 2 and 3 km/h were found to be 6.55 cm, 4.80 kg/ha, 0.88; 5.90 cm, 4.50 kg/ha, 0.90 and 6.57 cm, 3.92 kg/ha, 0.87, respectively. Considering the recommended ASS and SR of the crop, this plate could be selected. Similarly for *kodo* millet, performance parameters i.e. ASS, SR and Uc with MS_3 at forward speed of 1, 2 and 3 km/h were found to be 5.60 cm, 5.26 kg/ha, 0.91; 6.81 cm, 3.99 kg/ha, 0.91 and 7.47 cm, 3.0 kg/ha, 0.86, respectively. This plate provides higher uniformity among all the plates selected, but was not satisfying the minimum agronomical requirements of *kodo* millet in terms of seed rate consistency. Therefore, MS_2 plate was selected for sowing of *kodo* millet.

Effect of forward speed on different performance parameters of little millet

Performance parameters such as ASS, SR and U_c for little millet for three different sizes of slots are given in Fig. 4a, b, c. The agronomical requirements of the crops i.e. *kodo* and little millets are seed spacing of 5-7.5 cm and seed rate of 2-3 kg/ha. ASS, SR and U_c at forward speed of 1, 2 and 3 km/h for little millet with MS_1 were observed to be 11.29 cm, 1.08 kg/ha, 0.74; 10.86 cm, 0.97 kg/ha, 0.84 and 10.98 cm, 0.91 kg/ha, 0.74, respectively. The U_c was found to be more than 90% but, SR was far below the requirement. Hence this plate could not be utilized for sowing of little millet. Similarly , MS_2 at forward speed of 1, 2 and 3 km/h, the values of ASS, SR and Uc were observed to be 5.21 cm, 3.16 kg/ha, 0.84; 5.70 cm, 2.24 kg/ha, 0.82 and 6.84 cm, 1.59 kg/ha, 0.86, respectively. ASS and SR was closer to the recommended rate. Therefore, this plate can be utilized for sowing of little millet. Moreover, the values of ASS, SR and U_c for little millet with MS_3 at forward speed of 1, 2 and 3 km/h were observed to be 4.74 cm, 6.61 kg/ha, 0.88; 4.54 cm, 5.73 kg/ha, 0.87 and 4.33 cm, 5.04 kg/ha, 0.89, respectively. The values obtained against the agnominal requirements are at higher side, though the uniformity of distribution was highest among all the above plates, it could not be used for sowing of little millet. Hence, plate MS_2 was found suitable among different selected plates for little millet.

Effect of shutter opening percentage on fertilizer delivery

A study was also conducted using vertical metering device to select an optimum shutter opening percentage for recommended fertilizer rate for the crops. The vertical plate with slot size of 10 × 10 mm (diameter × width) with similar configurations was fabricated and fitted in the fertilizer box. Fertilizer was collected by rotating the plate through ground wheel at different shutter openings percentage. According to agronomical requirements, fertilizer rate for basal dose of selected millet is DAP of 110 kg/ha. The required fertilizer rate was obtained with corresponding shutter opening at 40% for *kodo* and little millets as compared to other openings. Therefore, the shutter opening of 40% was selected as it provides recommended dose of fertilizer for the millet crops.

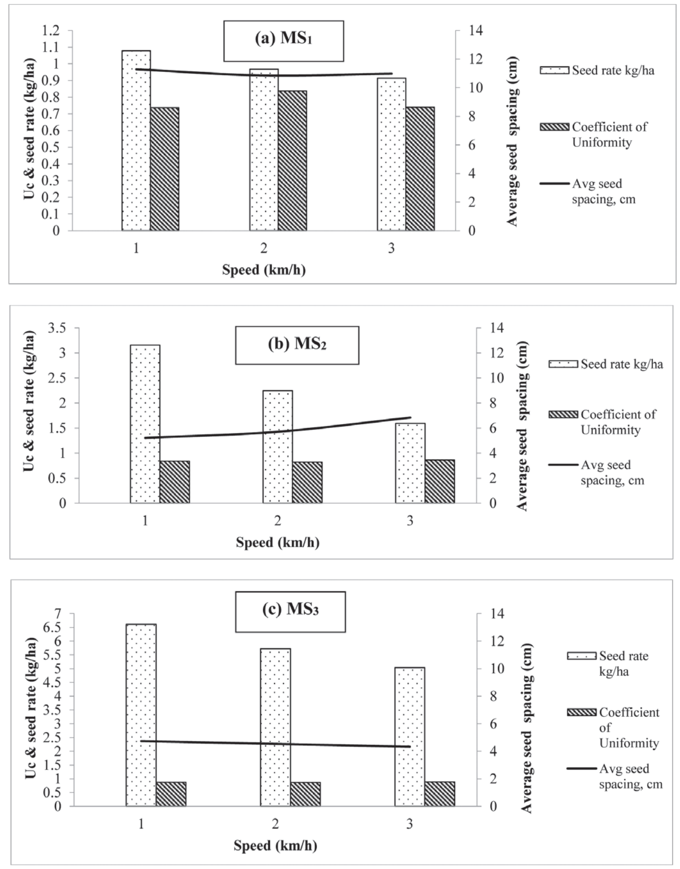

Fig. 4 : Performance parameters for MS1, MS2 and MS3 for little millet

Development of manually operated single row planter-cum-fertilizer drill

Based on the selected design parameters and results obtained from laboratory evaluation a manually operated single row millet planter cum fertilizer drill was developed. The model prototype drawings were prepared using CAD Pro Engineer Software as shown in Figure 5. It consisted of a hopper with vertical plates for seed and fertilizer metering, chain and sprocket power transmission system, shoe type furrow opener, seed delivery tube, main frame, ground wheel and a handle to operate the implement. Technical specifications of the developed planter cum fertilizer drill are given in Table 2.

Design of handle

Length of handle and angle of working tool with respect to soil surface are interdependent. Angle of operation is based on functional design and geometry of tool and generally lies between 30° to 45° and the recommended handle diameter for better grip is 30 to 35 mm. The average standing elbow height of Indian male and female workers is 1027 mm and 960 mm, respectively. So, in order to accommodate 5-95% percentile of operators, a 25 mm outer diameter mild steel pipe, 140 cm long was used for fabricating the frame and handle; and 3 mm outer diameter plastic gripper was fitted at the handle portion (Figure 5).

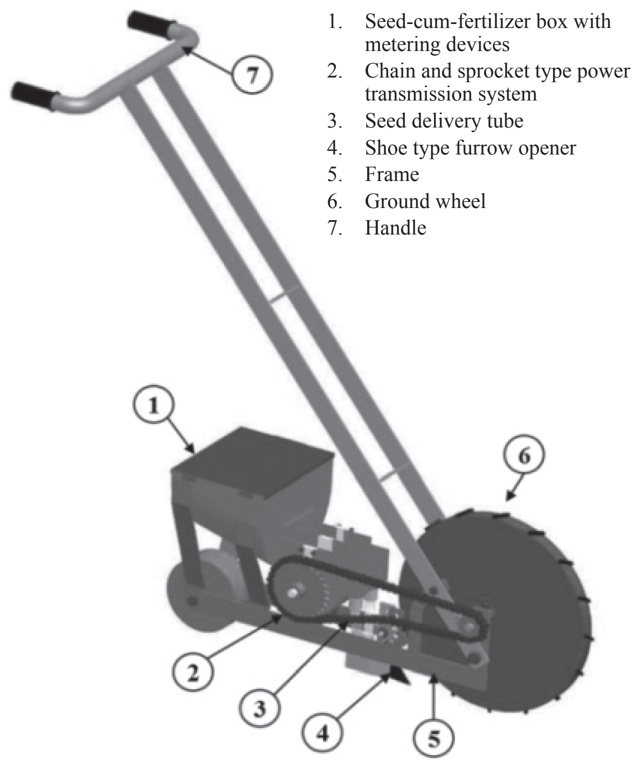

Fig. 5 : CAD drawings of manually operated single row planter cum fertilizer drill

Table 2 : Technical specifications of the developed implement

Parameter of planter-cum-fertilizer drill	Details
Overall dimensions, m, (L × W × H)	1.17 x 0.45 x 1.1
Overall weight, kg	20
Type of metering device for seed	Vertical plate
Type of metering device for fertilizer	Vertical plate
Diameter of metering device, mm	120
Number of slots on each metering device	24
Total number boxes and number of ground wheels	01
Type of furrow opener	Shoe type
Adjustment of working depth of furrow closer, mm	0–75
Diameter of ground wheel, mm	400
Plant spacing adjustment, mm	75-100

Field evaluation of planter cum fertilizer drill

The manually operated single row planter cum fertilizer drill developed for sowing of *kodo* and little millet was evaluated in the research farm of ICAR-Central Institute of Agricultural Engineering, Bhopal (Figure 6). Row to row spacing was maintained at 30 cm and the seeds used for the field testing had an average moisture content of 7% (db). Planter-cum-fertilizer drill was operated at an average forward speed of 2 km/h in vertisols (black cotton soil) and moisture content during planting was in the range of 14-20%. The forward speed of operation, row to row spacing, plant to plant spacing, depth of furrow, width of furrow and seeds/fertilizer delivered in the field by planter-cum-fertilizer drill were recorded. Based on data collected while in operation theoretical field capacity, effective field capacity and field efficiency were calculated according to Indian standard test code (IS 6316:1993). Cost of operation of machine and labour requirement were determined according to Indian standard test code (IS 9164:1979). Field performance parameters of the developed implement for small seed are given in Table 3.

Fig. 6 : Evaluation of the manually operated single row vertical plate planter cum fertilizer drill (MOVP)

Table 3 : Field performance parameters of the developed machine

Field parameter	Details	
Crop	***Kodo***	**Little millet**
Effective size of field, m^2	1000	1000
Average forward speed , km/h	2.04	2.01
Row to row spacing, mm	300	300
Plant to plant spacing, mm	100	100
Depth of furrow, mm	10 - 20	10 - 20
Width of furrow, mm	40 - 60	40 - 60
Seed rate, kg/ha	2.87	2.02
Seed saving in line sowing over traditional method, %	76.08	83.17
Seed saving over traditional method of broadcasting, %	90.43	93.27
Fertilizer rate, kg/ha	90-95	90-95
Actual field capacity, ha/h	0.048	0.05
Field efficiency, %	69	68
Labour requirement, man-h/ha	20.80	17.80
Cost of operation, ₹ /ha	750	662

The average plant spacing (APS), number of plants per meter run length in a row (NP) and number of tillers per plant (NOT) for *kodo* and little millet were measured for three randomly selected rows and the data was presented in Figure 7. The APS, NP and NOT for *kodo* millet was found 9.56cm, 16 plants/m and 10 tillers/ plant, respectively. The APS, NP and NOT for little millet measured and was found 8.9 cm, 17 plants/m and 13 tillers/plant, respectively. Comparison of the crops sown with broadcasted method and developed planter-cum-fertilizer drill shows that number of tillers grown was 2-3 times more with developed machine. Moreover, planter-cum-fertilizer drill can save seeds in the range of 76-93%. The obtained parameters with planter-cum- fertilizer drill were in acceptable range and matched with the plant population requirement of the selected crops.

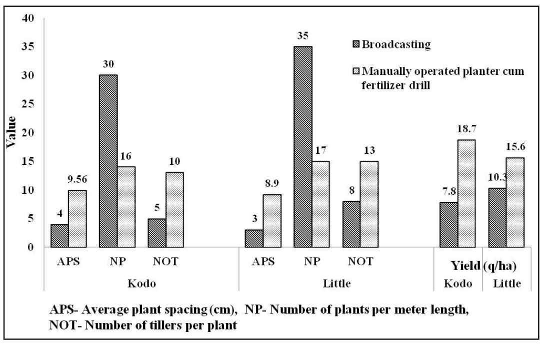

Fig. 7 : Plant spacing, number of plants per meter length, maximum number of tillers and yield (kg/ha) for kodo and little millet

Three randomly selected areas of 1 m^2 among the test plots marked and crop samples were collected for yield estimates. The yield of *kodo* millet obtained with broadcasting was 780 kg/ha whereas in case of developed planter-cum-fertilizer drill was 1870 kg/ha. Further, for little millet yield with planter-cum-fertilizer drill was found as 1560 kg/ha as compared to 1030 kg/ha with broadcasting. It was evident that the yield obtained with planter-cum-fertilizer drill was approximately two times more than that of broadcasting. Therefore, it was broadly concluded that practice with developed planter-cum-fertilizer drill will not only save precious quality seed but also offers more yield per unit area compared to traditional method of broadcasting. Moreover, field efficiency (%) of developed planter-cum-fertilizer drill was 69 and 68% for *kodo* and little millet respectively. Labour requirement (man-h/ha) was 20.8 and 17.8 h for *kodo* and little millets respectively. Cost of operation of ₹ 750/ha for *kodo* and ₹ 662/ha for little millets was calculated.

Conclusions

Vertical plate with slot size 3 × 3 mm was found suitable for *kodo* and little millet as it delivered optimum ASS, SR and U_c as 5.90 cm, 4.50 kg/ha, 0.90 and 5.70 cm, 2.24 kg/ha and 0.82, respectively. Then, another vertical plate with slot size 10 × 10 mm was found suitable for fertilizer metering at 40% shutter opening as it delivered required quantity of fertilizer for both the selected crops. The field capacity and field efficiency of the implement were found to be 0.048 ha/h and 69% for *kodo* and 0.05 ha/h and 68% for little millet, respectively. The developed implement coasting of ₹ 4000/-, whereas it's operational cost was found to be ₹ 750/ha for *kodo* and ₹ 662/ha for little millets. Yield obtained with developed planter-cum-fertilizer drill were 1870 kg/ha and 1560 kg/ha, which were 139% and 51% more when compared with broadcasting for *kodo* and little millet, respectively.

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