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RESEARCH ARTICLE

Development and evaluation of seed-cum-fertilizer drill suitable for low stature bullocks of Jharkhand

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ABSTRACT: Draught animal power is one of the major farm power sources of Jharkhand state which falls under agro-climatic zone VII (Eastern Plateau and Hilly region) due to poor financial condition of farmers and fragmented land holdings. Considering the draught animal size as well land holding capacity of farmers of Jharkhand state, an animal drawn multi crop seed-cum-fertilizer drill has been developed. The seed drill was evaluated in laboratory as well as in field condition. The average draft and power requirement of the developed seed-cum-fertilizer drill were 416.74 N and 0.372 kW, respectively. The average effective field capacity and field efficiency of the developed seed-cum-fertilizer drill were 0.069 ha/h and 65.9%, respectively at an average speed of 2.37 km/h. The cost of operation for sowing of wheat by developed animal drawn seed-cum-fertilizer drill was Rs. 1078/ ha whereas cost of sowing by existing animal drawn Birsa seed drill and traditional method (sowing behind country plough) were 2308 Rs./ha and 3675 Rs/ha, respectively).Thus, there is a saving of an amount Rs. 2597/ ha with the developed seed drill. The overall performance of the machine was found satisfactory for sowing of different crops (wheat, horse gram, upland paddy, black gram etc) in Jharkhand state.

INTRODUCTION

Sowing operation is one of the most essential farm operation related to crop production. The objective of sowing operation is to place the seed and fertilizer in rows at desired depth and seed to seed spacing, cover the seeds with soil and provide correct compaction over the seed. Manual sowing methods have various limitation viz uneven seed placement, time intensive and low efficiencies. Besides, these traditional sowing methods involve tedious works which causes fatigue and backache to operator due to the longer hours required for manual metering of seeds (Bamgboye and Mofolasayo, 2006). Increases in crop yield, cropping reliability, cropping frequency and crop returns depend on the uniform and timely establishment of optimum plant population (Behera et al., 1995). Due to lack of a proper sowing device, the adoption of line sowing is almost negligible in the state. The farmers are still using traditional method of sowing i.e. manual broadcasting of seeds by hands. Seed drill and planters place seeds at required spacing and provide better growing area per seed which ultimately affects crop growth and productivity (Karayel, 2009; Abd El-Lattief, 2014). Rice, wheat, horse gram, etc are the important cereal crops of India as well as Jharkhand state. Generally these are sown by traditional methods which consume lot of time as well as labor cost and don't give optimum seed rate. Wheat (*Triticum aestivaum* L.) is the second most important cereal crop of India and plays a vital role in food and nutritional security of the country. Total area of cultivation of wheat was 30.42 million hectares and production 92.29 million tons with average productivity of 3034 kg/ha during 2015-16. In Jharkhand, total area of cultivation of wheat was 0.16 million hectare and production 0.29 million tons with average productivity of 1835 kg/ha during 2015-16 (Anonymous, 2018).

With the modernization of agriculture, the use of mechanical power in cultivation has increased but draught power continues to be used on Indian farms due to small land holding and hilly terrain. Draft animal population is 49.69 million in India. Bullocks are the major draught

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animal in India having a population of 44.48 million (Anonymous, 2012). Population of draught animals of Jharkhand state has increased from 3.86 million to 4.055 million from 2007 to 2012, whereas, the other states scenario shows the decreasing trend (Anon. 2007 and Anon. 2012). Increasing trend of draught animals has been observed in six States, namely Jharkhand, Odisha, Chhattisgarh, Assam, Arunachal Pradesh and Mizoram. This may be due to geographical condition as well as less suitable for tractor power source. The density of draught animals is very high in 5 States (<1 ha/ animal) including Jharkhand, high in 6 States (1-2 ha/animal), medium in 8 States (2-4 ha/animal) and low in 8 States (>4 ha/ animal) (Chaudhuri and Singh, 2013). The command area of a pair of draught animal is about 2.5 ha and thus draught animal command 62.0 million ha of the net sown area of the country (approximately 44% of the net sown area. The equivalent power available is estimated as 12.18 Million kW from 48.73 million bovines in 2011-12 (Anonymous, 2012). The Draught Animal Power although has potential to generate annually 21924 million kWh energy (at 1800 working hrs per year) but due to declining use (350 working hour/year) the power availability has been limited to 4263 million kWh. Draft animals (working animals) play a dominant role in our rural economy. Out of total power available for agricultural operations in Jharkhand, major share is of animate energy (54%) followed by mechanical (43%) and electrical (3%) (Mishra and Choudhary, 2012). About 8-20% farmers are using tractor along with cultivator for ploughing purposes in which 2-3% farmers have their own and 15-18% farmers plough their land by custom hiring basis. Population of draught animals in the state is increasing; it still remains the major power source for farm operation for small and marginal farmers which constitute about 80% of total farmer (Chaudhuri and Singh, 2013 ; Kumar and Rusia, 2016). The population of draught animals in Jharkhand is 4.055 million among which population of bullocks is 3.60 million and buffaloes 0.45 million (Anonymous, 2012). Draught animals vary in size and capacities according to breed and area. Breed of the bullocks is local and named as Bachur. The body weight of majority of bullocks (86.5%) ranged between 180-340 kg which is less as compared to bullocks of other state. An average pair of bullocks generate draft between 400 to 600 N. Size of animals in the state is small and a pair is able to generate only 0.375-0.45 kW (Kumar and Rusia, 2016).The average land holding of the Jharkhand state falls under small category and topography/terrain does not permit use of heavy farm machinery. The average size of land holding in the State is 1.17 hectares as against all India average of 1.15 hectares (Anonymous, 2018).Several type of seed cum-fertilizer drills have been developed by various researchers (Gupta et al., 1999; Vatsa and Verma, 2000; Bhardwaj *et al.,* 2004; Varshney *et al.*, 2004 and Singh *et al*., 2017) for small fields. Similarly, under "AICRP on Farm Implements and Machinery" project as well as under "AICRP on Utilization of Animal Energy with Enhanced System Efficiency" several animal drawn implements have been developed and tested throughout India. But due to heavy weight as well as number of problems faced during operation, the seed drills were not suitable for the draught animals & soil conditions of Jharkhand state (Chaudhury and Singh, 2013; Anonymous, 2015 ; Kumar and Rusia, 2016).. Due to poor economic status, farmers cannot afford to purchase tractor drawn seed drill. Therefore, bigger size seed drills are not affordable and suitable as per the draught capacity of animals and economic conditions of farmers of Jharkhand. An animal drawn Birsa seed drill had been developed at Department of Agricultural Engineering, Birsa Agricultural University, Ranchi (Anonymous, 1983). It was suitable for sowing paddy, ragi, linseed, gram, sunflower and other small size seed in a single row.

Considering the draught animal as well land holding size of farmers of Jharkhand, development of animal drawn implements has a vital role to play in partial mechanization of the farms in the state to increase the efficiency and better utilization of draught animals. Therefore, there was need to develop a light weight animal drawn multi crop seed-cum-fertilizer drill for sowing of different crops.

MATERIALS AND METHODS

Design considerations

The basic design considerations had been taken during development of the seed drill were as follows:

i. Design is within the capability to pull by the pair of bullock power.

ii. The machine should be light in weight so that it can be transported easily from one place to another.

iii. The machine should be economical i.e. within the purchasing capacity of small and marginal farmers.

iv. It should be able to sow the seeds without damage.

v. It should be able to work under ploughed and unploughed conditions, meter the seed and fertilizer with required seed rate.

vi. Use of proper posture of the operator for efficient performance of the machine at a lesser fatigue.

vii. It should be easy in operation and maintenance.

viii. It should be easily fabricated by local manufacturers.

Development of an Animal Drawn Seed-Cum-Fertilizer Drill

Considering the draught animal size as well as land holding capacity of farmer of Jharkhand state, an animal drawn multi crop seed-cum-fertilizer drill has been developed at Department of Agricultural Engineering, Birsa Agricultural University, Ranchi (Jharkhand). The seed drill was designed and developed as per guideline of BIS standards so that it required less force, minimum damage, missing of seeds and also suitable for all type of soil during operation (Anonymous, 1973). The major components of developed animal drawn multi crop seed-cum-fertilizer drill were seed-cum-fertilizer box, seed and fertilizer metering mechanism, seed and fertilizer dropping unit, furrow openers, frame, power transmission unit, hitch and handle. Details of the components are as follows:

Seed-cum- fertilizer box

A trapezoidal shaped seed-cum-fertilizer box having overall dimension 480 × 440 × 280 mm was designed. The trapezoidal box had two compartments, one for the seed and other for fertilizer, which were mounted on the frame with the help of support. The box was made up of G.I. sheet of 18 gauges.

Seed and fertilizer mechanism

The seed metering mechanism for seed consisted of cast aluminum fluted roller. A shaft of 600 mm long and 20 mm diameter made up of mild steel were passed through fluted roller for rotating the roller. Seed rate was controlled by changing exposed length of the fluted roller in contact with seeds and fairly accurate seed rate can be achieved for a variety of medium size seeds like, paddy, wheat, black gram and horse gram etc. For getting proper seed and fertilizer rate the exposed length of roller was derived and adjusted accordingly. The exposed length of roller can be changed from 0 - 25 mm to set the seed rate.

Two adjustable orifice covered with spur wheel were used for fertilizer mechanism. Size of spur wheel was 75 mm diameter and 28 mm thickness, having 10 teeth. Two discs with groove cutter were provided for agitating the fertilizer which was attached with square shaft (500 mm length). It has an advantage of crushing the small clods of fertilizer, if it chocks the notch. Seed and fertilizer dropping unit consists of cup, adjusting lever, seed tube and seed boot.

Power transmission unit

The power transmission system consists of ground wheel, chain and sprocket mechanism. Ground wheel transmit the power to shaft connected with seed metering mechanism and fertilizer mechanism. The ground wheel consists of a bush, lugs and circular ring. Circular ring was fabricated with mild steel sheet of 305 mm diameter. Total 12 lugs were fabricated and welded on the periphery of the ring to develop better traction or grip in the soil. Diameter of ground wheel including lugs was 380 mm. The four sprockets were used on both seed and fertilizer mechanism shafts. Ground wheel was attached with 14 teeth (63.5 mm dia.) sprocket which transmit power to 18 teeth (75 mm dia.) sprocket attached on the fertilizer mechanism shaft. One additional 18 teeth (75 mm dia.) sprocket was also attached in the same fertilizer mechanism shaft to transmit the power to 14 teeth (63.5 mm dia.) sprocket attached with seed metering mechanism shaft.

Furrow openers

Design of furrow openers were made considering the available draft of 441 to 588 N for a medium pair of bullocks of Jharkhand state (Kumar and Rusia, 2016). The furrow openers were provided in seed drill for opening the furrow at uniform depth before dropping the seeds and fertilizers. The shoe type furrow opener with boot for seed and fertilizer tube were used. The furrow openers were designed at optimum rake angle of 25°. The share (125 × 80 × 8 mm) was made with high carbon steel flat. The share was welded to the shank. Size of shank was 340 × 40 × 4 mm, made of mild steel flat. Each furrow opener was provided with two boot of 18 gauge hole pipe, 20 mm inner diameter and 22 mm outer diameter 120 mm long, to receive tubes from seed and fertilizer metering device.

Seed and fertilizer tube

The seed and fertilizer were delivered by metering devices into feed cup there by it flows from tube and boot under gravity and placed into the furrow made in the soil. Uniform seed to seed spacing is achieved when all seeds are released by the metering device from the same height with the same velocity. The inclination of the seed tubes from the vertical is kept smaller than 20°. Polythene tubes with 25 mm diameter were used for connecting the feed cup and seed boot. The angle of impact of the seed in the furrow was 70-90° from the horizontal. The lower tip of the fertilizer tube should be 10 mm below the lower tip of the seed tube and should be minimum 25 mm above lowest point of boot.

Hitch

The hitch was made of two m.s. flat (40 × 4 mm) with 330 mm in length. The hitch was welded on the front side of the main frame. The height of yoke point would be adjusted with the help of nuts and bolts by changing the hitch angle of the frame with respect to beam.

Handle

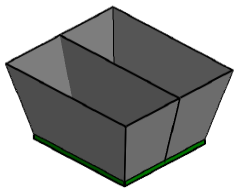
The handle considered as the main component determines

the working position of the operator. A handle was made of 408 × 40 × 4 mm mild steel flat. The grip of MS pipe 30 × 3 mm (diameter × thickness) 150 mm long was welded on upper end of M S flat and lower end of the handle were welded on the main frame.

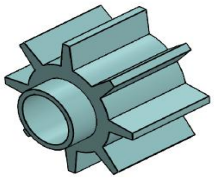
Frame

A rectangular frame (600 × 420 mm) was fabricated with four mild steel square pipes 40 × 4 mm. For seed box support 280 × 40 × 4 mm flat were welded to the frame. To rear end of the frame, the furrow opener is attached with the help of nuts and bolts. Different components such as furrow openers, transport wheel, handle, hitch and hopper were attached to the main frame. Furrow openers were attached to the frame by nut and bolt at desired spacing (18, 20, 22 and 24 cm).

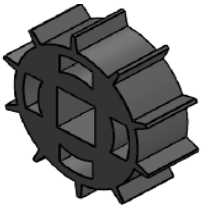
Isometric view of different components of the developed seed-cum-fertilizer drill Fig.1. Total weight of the machine was only 45 kg. Total fabrication cost of the developed animal drawn seed-cum-fertilizer drill was Rs. 8500 /-. The specification of the developed animal drawn seed drill is given in Table 1.



Seed-cum-fertilizer box

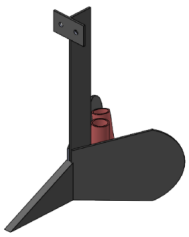


Seed metering mechanism



Fertilizer metering mechanism

Power transmission system



Furrow opener

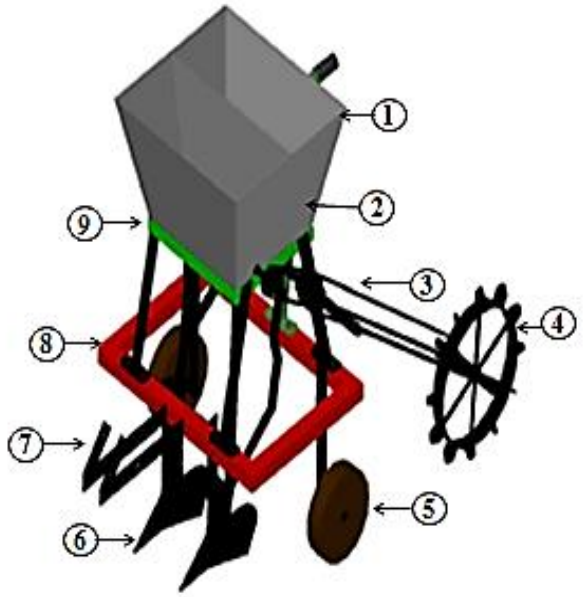
Handle

Fig. 1. Isometric view of different components of the developed seed-cum-fertilizer drill

Schematics diagram of the developed seed-cum-fertilizer drill developed in CAD is shown in Fig. 2. Pictorial view of the developed animal drawn multicrop seed-cum-fertilizer drill is shown in Fig. 3.

Table 1
Specifications of developed animal drawn seed-cum-fertilizer drill.

S. No.	Components	Specification
i.	Overall dimension (L×W×H), mm	600 × 420 × 900
ii.	No of furrow openers	2
iii.	Type of furrow openers	Shoe type
iv.	Type of Seed metering mechanism	Fluted type
v.	Type of fertilizer metering mechanism	Spur wheel type
vi.	Type of seed and fertilizer delivery	Gravity dropping
vii.	Detail of ground Wheel	
	(a) Diameter, mm	380
	(b) No. of spokes	6
	(c) Number of lugs	12
viii.	Seed-cum-fertilizer box	
	(a) No. of box	1 (Two compartments)
	(b) Shape	Trapezoidal
	(c) Materials	G.I Sheet (18) gauge
ix.	Details of Handle	
	(a) Height of the handle from ground, mm	800
	(b) Height of the handle from Frame, mm	510
	(c) Material	MS Flat (40×4 mm)
	(d) Grip diameter, mm	30
	(e) Grip length, mm	120
x.	Hitch	
	(a) Overall length, mm	330
	(b) Height from ground, mm	340
	(c) Material	MS Flat (40×4 mm)
xi.	Sprocket	
	(a) No. of Sprockets	4
	(b) No. of teeth	18 & 14(2 set)
xii.	Power source	Pair of bullocks
xiii.	Weight, kg	45



1. Seed-cum-fertilizer box, 2.Seed metering unit with hopper, 3. Chain drive, 4. Ground wheel, 5. Support wheel, 6. Furrow opener, 7. Hitch point 8. Main frame, 9. Frame for supporting hopper

Fig. 2. Isometric view of developed seed drill

Fig. 3: Developed animal drawn seed drill

Performance Evaluation of the Developed Animal Drawn Seed-cum-Fertilizer Drill

The developed seed-cum-fertilizer drill was tested at laboratory as well as in field condition. The seed drill was tested in the laboratory on four different seeds (Wheat, upland paddy, horse gram and black gram) and tested in the field on wheat and horse gram crop. Preliminary field trials were also conducted on upland paddy and black gram crops. The calibration of seed drill was carried out to study the effect of flute opening and speed of operation on seed rate and seed damage for wheat, horse gram, upland rice and black gram crops in laboratory condition. The developed animal drawn seed drill was evaluated on wheat and horse gram crop in field condition at Research Farm of Birsa Agricultural University, Ranchi (Jharkhand) during year 2017-2018.

The experiment was conducted in randomized block design (RBD) consisting of 3 treatments such as:

i. Developed animal drawn seed -cum-fertilizer drill (T_1),
ii. Existing animal drawn Birsa seed drill (T_2),
iii. Sowing behind country plough (T_3)

All three treatments were replicated thrice and were l allocated randomly in for sowing of wheat crop (Variety-K 9107). Individual plot size was 15 m × 10 m selected. During field operation draft, speed of operation, average depth of operation, field capacity and field efficiency were measured using standard procedure. The developed seed drill during sowing operation is as shown in Fig. 4. The depth of sowing was measured at different locations. The pull was measured using spring dynamometer. After germination of seeds in the field, measurement of agronomical parameters (plant population) of horse gram and wheat crop was done, Fig. 5. The cost of operation were calculated and compared with other sowing methods. Other management operations like fertilizer application, irrigation, harvesting and threshing etc were kept same under all treatments.

Fig. 4. Performance evaluation of the developed seed-cum-fertilizer drill during sowing


Fig. 5. Measurement of plant population of horse gram and wheat crop

RESULTS AND DISCUSSION

Crop parameter

The crop parameters were measured using standard methodology and the details of physical properties of different seeds (wheat, horse gram, upland paddy and black gram) are described in Table 2. The average length, width and thickness were found 5.25 mm (varied from 5.20 to 5.36 mm), 3.94 mm (varied from 3.88 to 3.95 mm) and 3.45 mm (varied from 2.40 to 2.48 mm) for horse gram where as it was 6.34 mm (varied from 6.34 to 6.38 mm), 3.34 mm (varied from 3.34 to 3.38 mm), 2.53 mm (varied from 3.53 to 3.56 mm), respectively for wheat crop. The average size or geometric mean diameter were found 3.77 mm and 0.59%, respectively for wheat crop.The average size or geometric mean diameter and sphericity for horse gram were found 4.15 mm and 0.79% , respectively. These parameters were considered for designing of seed metering mechanism.

Performance evaluation of the developed seed drill in laboratory condition

Calibration of the seed rate, fertilizer rate and seed damage were performed in laboratory condition using standard procedure.

As Jharkhand is a rainfed state, so it is very difficult to sow the crops at proper time. As per agronomical practices, the seed rate for the crops varied accordingly late or early sowing. So considering easiness of the work, the seed drill was calibrated in the laboratory for desired seed rate on upland rice, wheat, horse gram and black gram with different exposure length of metering mechanism. The seed rate at flute exposure length of 10 mm, 15 mm, 20 mm and 25 mm were found 31 kg/ha, 68 kg/ha, 104 kg/ha, 125 kg/ha, respectively on upland rice where as it was 26 kg/ha, 72kg/ha, 110 kg/ha, 130 kg/ha, respectively for wheat. Similarly, the seed rate of horse gram at flute exposure length 10 mm, 15 mm, 20 mm and 25 mm were found 20 kg/ha, 58 kg/ha, 90 kg/ha and 110 kg/ha, respectively, whereas, it was 21 kg/ha, 61 kg/ha, 98 kg/ha, 115 kg/ha, respectively for black gram. Variation of Seed rate of upland rice, wheat, horse gram and black gram at fluted roller opening is shown in Fig. 6. From the Fig. 6, it was observed that with increase in fluted opening, the seed rate is increasing. As per agronomical requirement of seed rate in Jharkhand state, 20 mm fluted opening is

Table 2.
Size and shape of some agricultural crops

Grain	Length (L), mm	Width / diameter (W), mm	Thickness (T), mm	Geometric mean diameter, mm	Sphericity	Bulk density, kg/m^3
Upland paddy	7.5	5.61	1.9	4.31	0.57	542
Wheat (Variety-K 9107)	6.34	3.34	2.53	3.77	0.59	785
Black gram	5.15	4.05	3.55	4.20	0.82	681
Horse gram (Birsa kulthi-1)	5.25	3.94	3.45	4.15	0.79	735

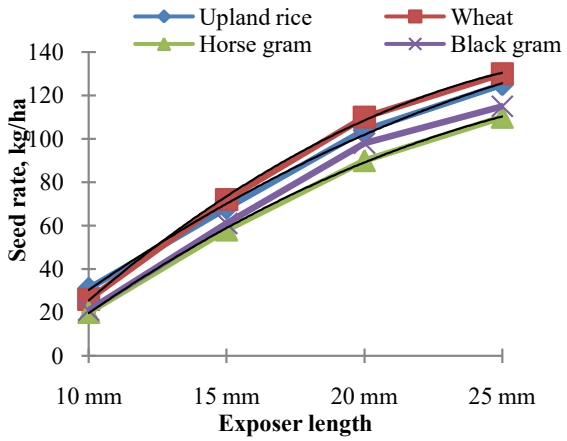


Fig. 6. Variation of Seed rate at different flute opening

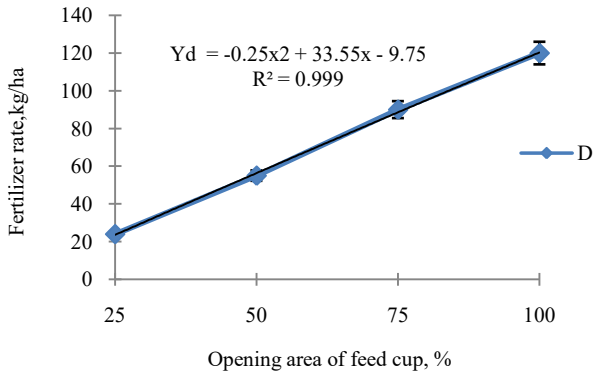


Fig. 7. Variation of fertilizer rate of DAP at feed cup opening

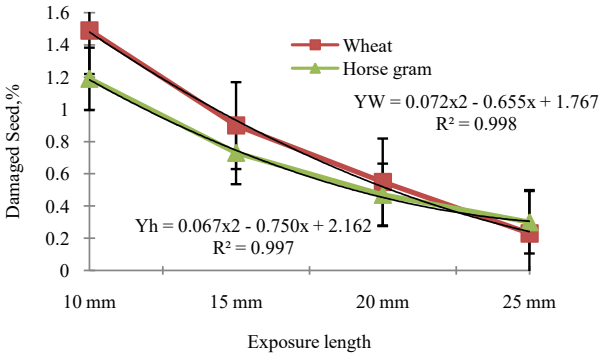


Fig. 8. Variation of seed damaged due to fluted roller opening on wheat and horse gram

more suitable for wheat and upland rice whereas 10 mm fluted opening is suitable for sowing of horse gram and black gram for timely sowing.

Considering the requirement of different dosages of fertilizer, the fertilizer rate varied according to the soil conditions in different part of the state. The fertilizer metering mechanism was calibrated with Di Ammonium Phosphate (DAP) for area of opening of feed cup. Fertilizer rate at 25%, 50%, 75% and 100% opening area of feed cup were found 24 kg/ha, 55 kg/ha, 90.82 kg/ha and 103 kg/ha, respectively. Variation of fertilizer rate of DAP at feed cup opening is shown in Fig. 7. The safe level of fertilizer application dose was up to 60 kg N/ha if seed and fertilizer are separately drilled through a combination opener in dispersed band into furrow under dry condition (Bhardwaj, 1971). From the figure, it was observed that with increase in feed cup opening of fertilizer metering mechanism, the fertilizer rate also increased. As per agronomical requirement of desired fertilizer rate, the percentage area of opening of feed cup can be adjusted.

Seed damaged was determined due to different fluted opening area of metering mechanism and different speed of ground wheel. During the laboratory test of developed Seed drill, drive wheel was rotated and it was observed that some seeds were damaged due to opening of fluted roller, increase in speed of drive wheel, moisture content and density of the seeds.

The average seed damaged at exposure length 10 mm, 15 mm, 20 mm and 25 mm were found 1.19%, 1.73%, 0.47%, 0.30%, respectively for wheat crop where as it was 1.66 %, 1%, 0.55%, and0.27%, respectively for horse gram crop. The percentage variation of seed damaged due to fluted roller opening on wheat and horse gram is shown in Fig. 8. The Figure shows that with increase in areas of opening of fluted roller, the percentages of seeds damaged were decreased. This may be due to friction between crop and surface. Standard fluted rollers are designed for seed rates of 20 to 120 kg/ha (Bhardwaj *et al.*, 2004). The minimum seed damaged was found at 25 mm opening fluted roller. The mechanical damage percentage of wheat and horse gram was very less. It was in the range as specified in Test code IS: 6813 (Anonymous 2000).

Performance evaluation of the developed seed drill on horse gram and wheat crops

The soil samples were collected randomly from 0 to 15 cm depth from 5 spots of the experimental field. Soil compositions were (Sand : 55.6%, Silt : 28.8% and clay : 15.6%). Soil pH, moisture content and bulk density were 5.52, 21% and 1.45 kg/m^3, respectively.

The performance evaluation of developed animal drawn seed-cum-fertilizer drill were conducted on horse gram and wheat crop as shown in Table 3. The speed of operation was determined by recording the average time required to cover 30 m row length for sowing wheat and horse gram crops. The average operational speed was found 2.43 km/h and 2.37 km/h for sowing of horse gram

Table 3.
Performance evaluation of developed animal drawn seed-cum-fertilizer drill on horse gram and wheat crops

S. No.	Parameters	Crops	
		Horse gram	Wheat
i.	Area covered, ha	0.045	0.045
ii.	Crop/ Variety	BirsaKulthi-1	K-9017
iii.	Seed rate	25 kg/ha	120 kg/ha
iv.	Fertilizer rate, kg / ha	20 N, 40 P_2O_5, 20 K_2O	80 N,40 P_2O_5,20 K_2O
v.	Row to row spacing, mm	240	200
vi.	Depth of sowing, mm	67.6	72.7
vii.	Average speed, km/h	2.43	2.37
viii.	Average Draft, N	418.5	416.7
ix.	Average power requirement, kW	0.362	0.372
x.	Field Efficiency,%	60	65.9
xi.	Effective Field Capacity, ha/h	0.062	0.069

and wheat crop, respectively. Similar studies have been done by the various authors such as Chakravati *et al.* (2004) ; Magaret *et al.* (2009) and Dhruwe *et al.* (2018) and reported that speed of operation by animal drawn seed sowing machine was in the range of 1.75 to 2.40 km/h.

The draft requirement for developed seed-cum-fertilizer drill was found 418.6 N and 416.74 N during the sowing of horse gram and wheat, respectively which was considered to be very well within the pulling capacity of small/ medium pair of bullocks of Jharkhand state. The power requirement for developed seed-cum-fertilizer drill was found 0.362 kW and 0.372 kW for sowing of horse gram and wheat, respectively. This is in the range from 0.277 to 0.447 kW power developed by a pair of bullocks in Jharkhand state as reported by Kumar and Rusia (2016).

The operational depth was measured with the help of measuring scale. The average depth of placement of seed and fertilizer of developed seed- cum- fertilizer drill was found 67.6 mm and 72.7 mm for sowing of horse gram and wheat, respectively.

The effective field capacity and field efficiency were found 0.062 ha/h and 60%, respectively at an average speed of operation 2.43 km/h during sowing of horse gram where as it was 0.069 ha/h and 65.9% at an average speed of operation 2.37 km/h for sowing of wheat. Similar studies have been done by the various authors such as Magaret *et al.* (2009); Patil *et al.*(2015); Dhruwe *et al.(*2018) and Singh *et al.* (2017).

Preliminary field trials of the seed drill were also conducted on upland paddy and black gram crops. The seed drill works satisfactory in all the above crops.

Comparative performance of developed animal drawn seed-cum-fertilizer drill against different sowing method on wheat crop

The field performance evaluations of developed animal drawn seed-cum-fertilizer, existing animal drawn Birsa seed drill and sowing behind plough were measured using standard methodology. The results of comparative performance of developed seed drill against different sowing methods on wheat crop is given in Table 4. Table

Table 4.
Comparative performance of developed seed drill against different sowing methods in wheat crop

S.No.	Parameters	Developed animal drawn Seed-cum Fertilizer drill	Existing animal drawn Birsa seed drill	Sowing behind the plough
i.	Location	BAU Farm	BAU Farm	BAU Farm
ii.	Area, ha	0.045	0.045	0.045
iii.	Crop/ Variety	Wheat /K -9107	Wheat /K -9107	Wheat /K -9107
vi.	Seed rate, kg / ha	120 kg/ha	120 kg/ha	120 Kg/ha
v.	Fertilizer rate, kg / ha	80N,40 P_2O_5, 20 K_2O	80 N,40 P_2O_5, 20 K_2O	80 N,40 P_2O_5, 20K_2O
vi.	Depth of sowing, mm	72.7	76.2	82
vii.	Average draft requirement, N	416.7	354.85	336.69
viii.	Average power requirement, kW	0.363	0.288	0.279
ix.	Average speed of operation, km/h	2.37	2.89	2.95
x.	Field efficiency, %	65.9	69	77
xi.	Effective field capacity, ha/h	0.069	0.0289	0.027

4 shows that the average depth of sowing by developed animal drawn seed-cum-fertilizer drill, existing animal drawn Birsa seed drill and sowing behind the country plough were found 72.7 mm, 76.2 mm and 82 mm, respectively. Average draft requirement for developed animal drawn seed-cum-fertilizer drill, existing animal drawn Birsa seed drill and sowing behind the country plough were 416.7N, 354.85 N and 336.69 N, respectively. Similarly, the average power requirement for developed animal drawn seed-cum-fertilizer drill, existing animal drawn Birsa seed drill and sowing behind the country plough were 0.372 kW, 0.288 kW and 0.279 kW, respectively. The average effective field capacity was maximum in case of sowing seeds with developed animal drawn seed drill (0.069 ha/h) followed by existing animal drawn Birsa seed drill (0.028 ha/h) and sowing behind country plough (0.027 ha/h).

Agronomical parameter

Agronomical parameter like germination, plant population/ m^2, pod/m^2 and grain yeild were recorded for wheat crop. The average results of the agronomical parameters of wheat crop, Fig. 9. The average plant population per square meter was maximum in sowing behind plough (149 No/ m^2) followed by developed animal drawn seed drill (112 No/ m^2) and existing animal drawn Birsa seed drill (91No/ m^2). Similarly, average tillers per square meter at 45 DAS were maximum in developed animal drawn seed-cum-fertilizer drill (321 No/ m^2) followed by existing animal drawn Birsa seed drill (284 No/ m^2) and sowing behind country plough (264No/ m^2).

The average ear head per square meter was maximum at developed animal drawn seed drill (292 No/ m^2) followed by existing animal drawn Birsa seed drill (252 No/ m^2) and sowing behind country plough (243 No/ m^2). The average grain yield was higher at developed animal drawn seed-cum-fertilizer drill (2890 kg/ha) followed by existing animal drawn Birsa seed drill (2630 kg/ha) and sowing behind country plough (2500 kg/ha).

Cost economics of sowing of crops by the Animal drawn seed-cum-fertilizer drill

The cost of economics was calculated using standard methodology. The cost of operation of the developed seed drill was found 1078 Rs/ha.

Economic analysis of developed animal drawn seed-cum-fertilizer drill was campared with existing animal drawn Birsa seed drill, sowing behind the plough .One man required for developed animal drawn seed-cum-fertilizer drill and existing animal drawn Birsa seed drill and 3 man for sowing behind the plough.

The man-hours requirement for sowing wheat in one hectare land was maximum in case of sowing behind the plough (37 h/ha) followed by existing animal drawn Birsa seed drill (34.6 h/ha) and developed animal drawn seed-cum-fertilizer drill (14.5 h/ha).The average cost of operation per hectare of land was minimum in case of developed animal drawn seed-cum-fertilizer drill (Rs1078/ha) followed by existing animal drawn Birsa seed drill (Rs 2308/ha) and sowing behind plough(Rs 3675/ha).The result of comparative cost economics of developed animal drawn seed-cum-fertilizer drill is given Table 5.

Fig. 9. Effect of different sowing method on agronomical parameters for wheat crop

Table 5.
Comparative cost economics of developed animal drawn seed-cum-fertilizer drill with other sowing methods

S.No.	Parameters	Developed animal drawn Seed-cum Fertilizer drill	Existing animal drawn birsa seed drill	sowing behind country plough
i.	Average man hour requirement, h/ha	14.5	34.6	37
ii.	Cost of operation, Rs/ha	1078	2308	3675

Note: Hiring charge of animal with plough man @ Rs. 500 /- per day and a labour @ Rs. 285 /- per day. (Excluding land preparation charge)

CONCLUSION

The developed animal drawn seed drill worked satisfactory in actual field condition for sowing of different crop seeds. It will be useful for small and marginal farmers of tribal areas of Jharkhand. The draft requirement of developed machine was within the pulling capacity of local small/ medium bullocks. Only one operator is required to operate the machine. The machine can be easily transported from one field to another field. The seed drill can be used to sow the seeds on the field at required row to row spacing and simultaneously place the fertilizer in the same row. The average draft and power requirement of the developed seed-cum-fertilizer drill were 416.74 N and 0.372 kW, respectively. The average effective field capacity and field efficiency of the developed seed-cum-fertilizer drill were 0.069 ha/h and 65.9%, respectively at an average speed of 2.37 km/h. The overall weight of the seed drill was only 45 kg and works satisfactory in all types of soil.

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