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Redesigning of Asella Animal Drawn Wheat Row Planter

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ABSTRACT

This study was undertaken to redesign, fabricate, and evaluate the performance of animal-drawn seed drill prototype capable of drilling wheat and barley seeds and applying fertilizer at predetermined row spacing and depths. The physical properties of seeds involved in the study were investigated to optimize the design of the seed drill's components. The developed seed drill machine, consists of a frame, seed and fertilizer hopper, seed metering devices, seed delivery tube, adjustable furrow opener, and drive wheels. The performances were evaluated in terms of Seed and fertilizer rate, row spacing, depth of seed placement, plant count/stand, field capacity and field efficiency. The investigation revealed that the sphericity of Hidase, Digelu, Ogolcho, and Kekeba wheat varieties were 65.81 %, 64.79% and 62.62 %, respectively. Row-to-row spacing can be 20 cm and depth also adjustable to 5 to 7 cm as per wheat agronomic requirements. The developed four row animal drawn seed drill was tested in the laboratory and field. The seed rate was calibrated and observed that 127 kg/ha with a middle flap position adjustment lying in the acceptable range of the recommended seed rate. There was no visible damage observed. The mean field capacity and field efficiency were 0.112 ha/hr and 81.78% at speed of 1.71km/hr. 310 to 318 plant populations per meter square (1 m^2) area were observed during field germination count. Based on the performance evaluation results, it is concluded that the developed seed drill can be effectively and economically used by most farmers.

INTRODUCTION

Wheat is the second important cereal crop in Ethiopia with an annual production of about 3.43 million tons cultivated on area of 1.63 million hectares (CSA, 2013). According to CSA (2013) wheat occupied about 17% of the total cereals cultivated area with average national yield of 2.11 t/ ha which is low compared to the world average of 4 t/ha (FAO, 2009).

These low production and productivity of the crop are all attributed to low use of improved farm inputs (biological and mechanical), dependency on traditional farming system and rainfall. Traditional farming system in the country is the major factor contributing to lower production. The traditional method of row planting method is tedious, causing fatigue and backache due to the longer hours required for careful hand metering of seeds and fertilizer. The importance of machine in agricultural operations in the world today should never be underestimated, be it manually operated or powered. One of the major problems confronting the farmers in Ethiopia is in the area of planting seeds because of the limited economy they can put up and most of them cannot afford the money to procure or hire sophisticated machinery that can be used for planting.

The planting operation is one of the most important cultural practices associated with crop production. Increases in crop yield, cropping reliability, cropping frequency and crop returns all depend on the uniform and timely establishment of optimum plant populations. Proper application of fertilizer at proper location and proper placement of seed row spacing has a good effect on yield growth. The main reason for increase in yield is the uniform and controlled application of fertilizer with respect to seed in a concentrated bond at about 50 mm below and 50 mm away from the seed.

A developing country like Ethiopia is expected to continue to rely more on animal drawn tools for the predictable future for crop cultivation. The use of animal drawn tools for crop cultivation is still predominant in Ethiopia because tractors require resources that many farmers do not have easy access to tractors. These small holder farmers still continue to plant manually, the result of which is low productivity of the crops. It is therefore necessary to develop a low cost animal drawn row planter that will reduce tedium and drudgery and enable small holder farmer to produce more foods and also environmental friendly.

Under intensive cropping, timeliness of operations is one of the most important factors which can only be achieved if appropriate use of agricultural machines is advocated. Manual method of seed drilling, results in low seed placement, spacing efficiencies and serious back ache for the farmer which limits the size of field that can be row planted.

The federal and regional agricultural engineering research centers have been tried to develop and adapt prototypes of wheat row planters. Other private companies and individuals including farmers are also develop row planting implements to commercialize on larger scale. Various types of wheat row planter have been developed with different design approaches which have their advantage and disadvantages and also operational limitation.

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Asella Agricultural Engineering Research Center has been developed, modified, evaluated and demonstrates continuously from four up to eight row animal drawn wheat seed drill. These seeder were designed to plant only wheat at a seed rate of 125 to 150 kg/ha with no fertilizer metering device, i.e fertilizer were broadcasted by hand before sowing of wheat. Even though, wheat seed drills were designed, modified, tested and evaluated continuously by different researchers at the center, still there is no proven wheat seed drill that can be used under farmers' conditions.

In general, the drawback observed to-date is that available wheat seed drills are not able to maintain uniform seeding rate, fertilizer and seed application at a time. To achieve the best performance from a seed driller, the observed limitations would be optimized by proper design and selection of the components required on the machine to suit the needs of crops. Therefore, this research activity was initiated to redesign, develop and evaluate the improved animal drawn wheat seed drill.

MATERIAL AND METHODS

This section deals with the materials and methods employed for the development of four row animal drawn wheat seed drill. The materials used to develop the planter and equipment used to test the developed row planter has been discussed under respective title.

Physical Properties of Some Selected Wheat Variety

The physical properties of seeds are important factors for the design of different components of the machine. The most common wheat varieties of Digelu , Kekeba and Ogolicho wheat seed varieties were selected for the study to determine the geometrical size of the seed based on their physical properties. Parameters like thousand grain mass, geometrical size, sphericity, bulk density and angle of repose were considered.

Descriptions of Improved Row Planter

The developed animal drawn wheat row planter prototype (fig.1) were simple and consists of the following main components; frame, seed and fertilizer hoper, furrow openers, ground wheel, metering device (flute), seed and fertilizer delivery tubes, hitching system, handle and beam.

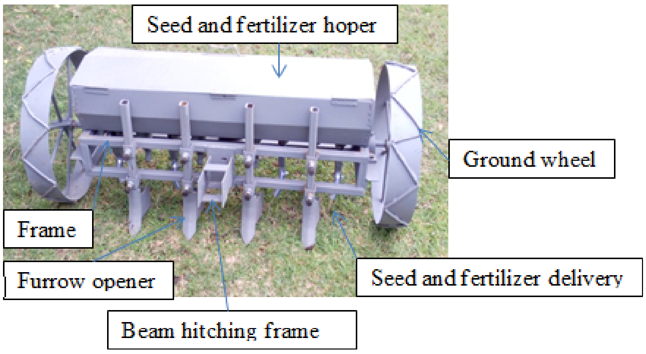

Figure 1: Components of designed garlic bulb breaker

Frame

The frame is the skeletal structure of the planter on which all other components are mounted on it. Frame of planter has to be rigid and strong as all parts are mounted on it. It is made from mild steel square pipe (fig.1). The furrow openers, metering mechanism, handle, hitch attachment and hopper were attached to the frame.

Seed and Fertilizer Hoper

The hopper is feed in a vertical position only. The material used for the construction was sheet metal with thickness of 1.5 mm. For designing the seed hopper, the average bulk density of wheat seeds 791.5 kg/m^3 and the angle of repose 26.090 were considered. Therefore, the angle of the hopper side wall was kept as 62°. Hence, the designed hopper has trapezoidal shape at the bottom half and rectangular shape at upper half height and divided into two compartments along its length; one for fertilizer and the other one for seeds. The volume of hopper was determined using the following formula (Olaoye & Bolufawi, 2001).

$$V = \frac{S_R}{nBD}$$

Where:

SR = seeding rate (kg/ha)

n= number of refilling per hectare

BD= bulk density of the seeds (kg/ m^3)

$$V = \frac{125(Kg/ha)}{8 \times 791.5(Kg/m^3)} = 0.02\,m^3$$

Actual volume of the seed hopper was determined on the basis of the assumed dimensions of the box listed below.

Top width (b) = 28 cm

Bottom width (a) = 20 cm

Height (hR) = 9 cm

Height (hT) = 8.5 cm

Length = l = 94cm

VR = Volume of rectangular part of the hoper

VT = Volume of trapezoidal part of the hoper

Using the above assumed dimension of the box, its volume was calculated by the following formula (Sharma and Mukesh, 2010).

$$V = V_R + V_T = l * b * h_R + \frac{1}{2}(2*a + 2*l)*h_T*b$$

$$V = V_R + V_T = 94*28*9 + \frac{1}{2}(2*20 + 2*94)*8.5*28$$

$$V = 50{,}820\, cm^3 = 0.05\, m^3$$

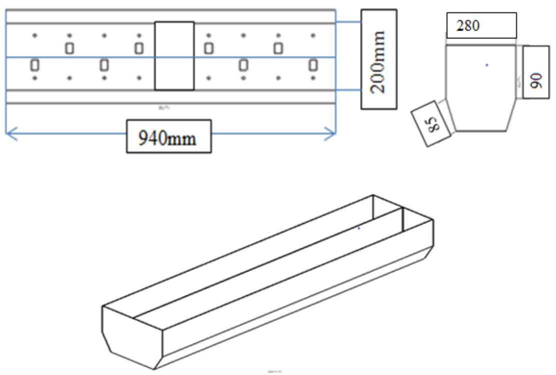

Figure 2: Isometric view of seed and fertilizer hopper

Hence, designed hopper has two compartments and equally separated, one for seeds and one for fertilizers which is 0.025 m^3 separately as shown in figure 4.

Metering Mechanism

Metering mechanism is the heart of planting machine which is distributes seeds uniformly at the desired application rates. The metering flute roller is derived directly by the ground wheel through drive shaft. The length, depth and number of flute on the seed metering roller were determined from the recommended seed rate per hectare. In this design, the seed metering flute lifts the seeds from the bottom flap of flute house and drops the seed and fertilizer into seed tube. The size of flutes was determined on the basis of recommended seed rate per hectare (RNAM, 1991).

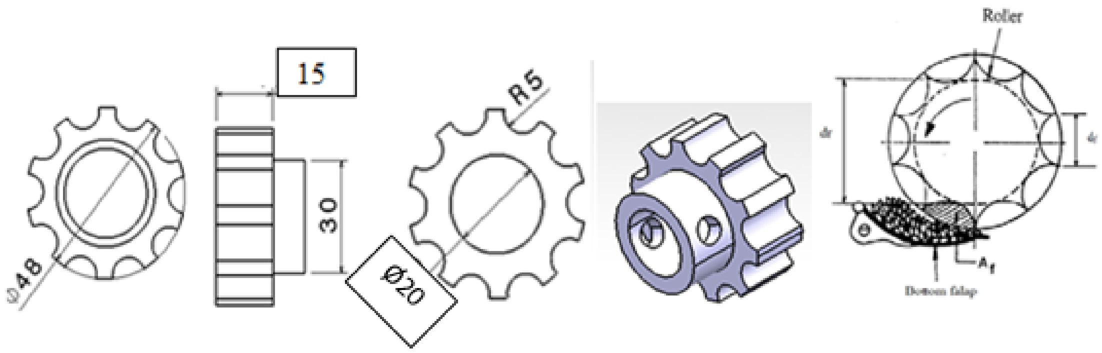

Figure 3: Schematic diagram and isometric view of fluted roller

Adjustable Furrow Openers

Furrow openers were attached to the front side of frame which is used to open the soil for seed and fertilizer placement. As the furrow openers open the soil, the seeds and fertilizers come from delivery tube drops into the opened furrow. Furrow openers were fitted on the main frame of the planter with bolt and nut with provisions of adjusting the depth by moving furrow openers vertically as shown in figure 1.

Seed Tube

Seeds and fertilizer pass through delivery tube into opened furrow. The seed tube delivers the seeds and fertilizer at a desired uniform spacing into the opened furrow. Seed and fertilizer delivery tubes were provided for safe conveying of seed and fertilizer from metering unit into furrow created by furrow opener. A circular rubber hose pipe of 20 mm diameter was attached to the tube made at the lower part of the metering flute house (discharge spout).

Hitching System

As the sowing implement was to put in the field and would have to operate parallel to the ground level by a pair of oxen, a circular wooden beam of 2800 mm length was pinned at its end by two round bar pins in the angled MS flats. The hitch was welded on the front side of the main frame. The MS flats were drilled two holes of 8 mm diameter at 60mm, center to center distance. Three MS flats (40 x 70 mm) were welded on the tip of MS flats of length 180 mm.

Handle and Beam

The handle considered as the main component and determines the working position of the operator. The height of handle was kept little more so that pressure can be applied on the grip of handle at the applied forces and the height of handle remains within the reach of operator. The handle was made of MS flat (150 x 90 mm) was welded on main frame and 120 mm length water pipe of 45 mm diameter was welded on the middle of MS flat and 120 mm length wooden beam insert and pinned to the pipe.

Ground Wheel

The ground wheel is designed as an integral part of the seed metering mechanism connected to the seed metering device directly through shaft. The rims of the wheel were made from mild steel sheet metal of 2 mm thick and 80 mm wide. Each wheel have eight spokes made from mild steel rods with diameter of 8 mm and length of 280.5 mm, and welded to the rim and hub at the center used as bushing or shaft bearing, at equal interval as shown in figure 4. On the circumference of ground wheel, lugs made from mild steel round bar were provided to develop better traction or grip on the soil.

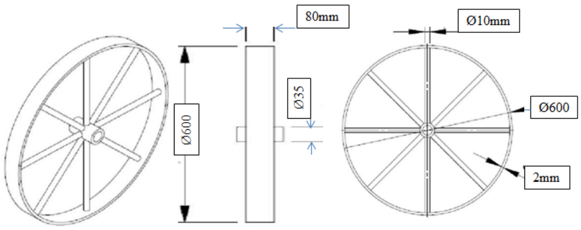

Figure 4: Isometric view of ground wheel

Working Principles of Row Planter

The principle of operation of the planting machine is very simple and requires only one man to operate. Seed drilling is accomplished by just pulling the planter in a prepared field. Since the metering flute roller is directly attached to the ground wheel through shaft. Ground wheel rotates the metering flute roller also rotates, seeds and fertilizer automatically dropped into the opened furrow through the seed delivery tube.

Performance Test and Evaluation

Before actual field performance test was carried out in the lab or field, the planter was tested to confirm the workability of all the functional components, to determine and check any malfunctioning parts and defects in the manufacturing.

Laboratory Performance Test

The machine was calibrated in the laboratory to determine the rate of seed discharge and seed damage. The planter was suspended on a vice and the hopper was loaded with wheat seeds. A paint mark was made on the drive wheel to act as a reference point to count the number of revolutions when turned and a seed collecting bag was placed on the discharge tube to collect the seeds discharge and weighed. The drive wheel was rotated 10 times at constant speed. The test for percentage seed damaged was done with the machine held in a similar position of calibration.

Soil Moisture Content

Soil moisture content on wet basis of soil was measured by oven dry method. The soil samples from test plot were taken using core sampler 80 mm diameter and 120 mm in length and a soil auger. The collected soil samples from each location were weighed initially and then kept in an oven for 24 hours at 105°c for obtaining dry weight of soil and moisture content was calculated following standard procedure as follows:-

$$M_C = \frac{W_w - W_d}{W_w} \times 100$$

Where:
MC = Moisture content of soil (%) on wet weight basis;
Ww= Weight of wet soil, g; and
Wd = Weight of dry soil, g.

Bulk Density

Bulk density of the soil is the oven dry mass per unit volume of the soil. It was determined by core sampler method. The core sample of soil of known volume was collected and weighed. The bulk density was calculated by using formula:-

$$\rho = \frac{M}{V}$$

Where, ϱ = Bulk density of soil, g/cm^3
M = Oven dry mass of soil contained in core sampler, g
V = Volume of core sampler, cm^3

Width and Depth of Operation

The depth of sowing was measured at different locations with the help of depth scale by putting a tip of depth scale in a furrow base and its average was taken as operating depth. The width of operation was calculated by dividing the total width of plot by the number of passes.

Operating Speed

The operating speed of row planter was carried out by observing the time required for traveling 40 m distance with the help of stop watch and calculated as follow:-
S=(D/t)*3.6
Where: -
S = digging speed, km / h.
D = travelling distance, m.
t = time, s.

Theoretical Field Capacity

Theoretical field capacity was is the rate of field coverage of the implement, based on 100 per cent of time at the rated speed and covering 100 per cent of its rated width as follows:-
TFC= (S*W)/10
Where: -
TFC = Theoretical field capacity, ha/h.
S = Operating speed, km / h.
W = Working width, m.

Actual Field Capacity

Actual field capacity was measured by taking an area of 40 x 20 m^2 (i.e. 0.08 ha) and measuring the time in actual field condition. It includes turning loss, filling time and any other. There was continuously operated in the field for 0.08 ha to assess its actual coverage. The time required for complete application was recorded and effective field capacity was calculated.
EFC= (A/T)*C
Where: -
EFC = effective field capacity, ha/h.
A = plot area, m^2.
T = time, sec.
C = unit conversion factor

Field Efficiency

The field efficiency is the ratio of the effective field capacity to the theoretical field capacity, the field efficiency was calculated.
FE= (EFC/TFC)*100
Where
TFC = theoretical field capacity, ha/h.

EFC = effective field capacity, ha/h.
FE = field efficiency, %

Cost Analysis
When a new technology is introduced to the farmer, they are interested to know whether the machine will be profitable to them or not. Cost analysis is very important for a new technology. Operational cost of the machine is the sum of fixed cost and operational cost of the machine. The total cost of the machine was determined by knowing the cost of the materials used for fabrication of the seed driller and fabricating cost of the machine. The following assumptions were made in determining the cost of operation of the row planter:

i. Expected life of the machine 10 years
ii. Annual use of machine 30 days per year
Total annual use = 30 × 8 h/year = 240 h/year
iii. Selvage value of the planter 10 percent of initial cost

Fixed Cost
It is the total cost of depreciation, interest on investment, tax, insurance and shelter. For calculating the depreciation of the machine, straight-line method was used.

Depreciation

$$Depreciation\,(Birr/hr) = \frac{P-S}{L*H}$$

Where, P = purchase price (Birr),
S = Selvage value (Birr),
L = Useful life (Year)
H = Working hours per year

Annual interest @ 15 % in investment
I=(P+S)/2 x (i/H)
Where,
I = Interest Birr per hour;
i = Interest rate (a) 15%.
Shelter,Tax and Insurance,ST=2.5%p

Variable Cost
Repair and Maintenance
Repair and maintenance cost was taken as 3.5% of initial investment

R&M cos t=(3.5×P)/(100×H)

Hire Charges of Pair Oxen with Operator
The local custom hire charge of pair oxen with operator = 50 Birr/hr
Total variable cost = Repair and Maintenance cost + Hire charge
Total cost ofseeddrilling(Birr/hr)=Fixed cost (Birr/hr)+Variabl cost (Birr/hr)
Costofsowingoperation(Birr/ha)=(Total cost (Birr/hr))/Effectivefieldcapacity(ha/hr)

Data Analysis
Simple descriptive statically analysis was used for the analysis of the mean values of data obtained from lab test and field evaluation.

RESULTS AND DISCUSSION
The experiments were conducted for four row animal drawn wheat crop planter in the laboratory as well as in the field. The performance of the machine was evaluated at the field of selected farmers at Hetosa district of Arsi Zone, considering seed rate, effective field capacity and field efficiency.

Physical Properties of the Seeds
Physical properties of the seeds are important for optimizing the design parameters of the seed driller. The most popular wheat varieties of Digelu, Kekeba and Ogolcho were selected for the study. The size and shape of the seed was considered to relevant to the design of cell size on its periphery of metering flute roller and seed hopper. The slope of the hopper was selected on the basis of angle of repose of the seed. Their observed physical properties were presented in table 1.
The mean length (L), width (W), thickness (T), size, sphericity, thousand grain mass (TGM), angle of repose (AR) and bulk density (B.D) of selected wheat variety were determined and ranges from 5.49 to 6.12mm, 3.21 to 3.49 mm, 2.67 to 2.81 mm, 2.60 to 3.90 mm, 62.62 to 65.81%, 31.83 to 34.76 gm, 25.44 to 26.97 degree and 781.54 to 801.91 kg/m^3 respectively.

Table 1: Physical properties of digalu, kakeba and ogolcho wheat seeds varieties

Physical properties	Samples size	Digalu	Kekeba	Ogolcho	Unit
Length (L)	30	5.49±1.23	6.12±0.58	6.03±0.29	mm
Width (W),	30	3.24±1.23	3.49±0.45	3.21±0.25	mm
Thickness (T)	30	2.67±0.89	2.81±0.45	2.8±0.19	mm
Size	30	3.60±0.350	3.9±0.32	2.77±3.70	mm
Sphericity	30	65.81±6.14	64.79±2.87	62.62±2.81	%
TGW	5	31.83±3.14	34±0.44	34.76±0.47	gm
Angle of repose	5	25.86±0.84	25.44±0.74	26.97±0.94	degree
Bulk density	5	791.15±2.94	781.54±2.48	801.91±2.48	kg/m^3

Mechanical Damage to Seed by Metering Mechanism

The mechanical seed damage is defined as injury to seeds, partially or completely by the seed metering of row planter. During the laboratory test of the row planter, drive wheel was rotated at animal walking speed. The observations of the mechanically damaged seeds of 1000g seeds were used for the testing; the variation of the damage seeds was found 0.06 to 0.12g seeds for different replications. The average percentage of the mechanically damaged seeds for Ogolcho wheat seed variety was found 0.0082%. Abiy Solomon (2017) found mean percent seed damaged for a Kekeba wheat variety seed was found to be 0.0088%. However, the internal damage of seeds was measured by germination test was found 98.78 % germination rate which is greater than that of predicted by seed supplier (98.7 %).

Table 2: Mechanical damage to wheat seeds by seed drill

Sr.no	Crop variety	Total weight of sample (g)	Weight of broken seeds (g)	Percentage of damaged seeds %
1	Ogolcho	1000	0.12	0.012
2	Ogolcho	1000	0.08	0.008
3	Ogolcho	1000	0.10	0.004
4	Ogolcho	1000	0.11	0.011
5	Ogolcho	1000	0.06	0.006
Average			**0.082**	**0.0082**

Effect of Flap Position on Seed Rates

Seed rate calibration is necessary to calibrate the planter before putting it in actual use to find the desired seed rate. It has been done to get the predetermined seed rate of the planter. Ogolcho variety was used for laboratory calibration by varying the flap position at upper, middle and lower (fully opened). A plastic bag was attached to each seed tubes to collect the seeds. The average seeds collected in the laboratory were observed as, 118.07, 127.07 and 141.26 kg/ha for upper, middle and lower as shown in table 3. Data revealed that with middle flap position gave nearest values of seed rate in the range of 126.85 – 127.27 kg/ha. Average value of 127.07 kg/ha was obtained which is nearest to the recommended seed rate of 125 kg/ha of wheat.

Table 3: Mass of seeds collected from each furrow opener per 100 m length

Flap position	Replication	F1	F2	F3	F4	Total Seed Collected (gm)	Seed Rate (kg/ha)
Upper	1	235.34	239.19	230.30	234.71	939.54	117.44
	2	239.80	238.67	240.47	232.50	951.44	118.93
	3	235.80	231.10	241.33	234.67	942.90	117.86
Average		**236.98**	**236.32**	**237.36**	**233.96**	**944.62**	**118.07**
Middle	1	253.80	250.77	254.97	255.27	1014.81	126.85
	2	252.33	258.23	251.43	254.70	1016.69	127.08
	3	254.20	252.93	257.33	253.70	1018.16	127.27
Average		**253.44**	**253.97**	**254.57**	**254.55**	**1016.55**	**127.07**
Lower	1	278.33	283.3	280.13	289.43	1131.19	141.39
	2	277.62	288.07	283.78	285.45	1134.92	141.86
	3	283.66	272.33	285.29	282.97	1124.25	140.53
Average		**279.87**	**281.23**	**283.06**	**285.95**	**1130.12**	**141.26**

Effect of Hopper Filling Level on Seed Rates

Table 4 shows the effect of hoper filling level on seed rate variations. It was observed that the entire samples collected for each hopper filling (Full, 3/4th and half) at middle flap position was nearly the same and there was little deviation among the samples.

Table 4: Mean mass of seeds collect for different hopper filling level at middle flap position

Observation	Seed rate (kg/ha)		
	Halve	**Three fourth**	**Full**
1	128.2	128.08	127.93
2	127.72	126.9	127.16

3	127.45	127.88	129.15
4	126.64	128.63	126.5
Mean	**127.5**	**127.87**	**127.68**

Field Test

The developed row planter was tested on farmers' wheat fields for its actual performances on plot of (20m x 40m) at Hetosa district. Ogolcho wheat variety was used for the study.

Moisture Content and Bulk Density of Soil

Five soil samples were taken randomly at different location of the field at 15 cm depth from the surface of soil before operation of planter using core sampler of 8 cm diameter and 8 cm height. Average values of moisture content and bulk density were observed as 19.25% on dry basis and 15.49% on wet basis and 1.45 g/cm^3 respectively for experimental field as presented in table 5.

Table 5: Moisture content and bulk density of soil

Observation	Weight of a soil (g)	Weight of oven dried soil (g)	Moisture Content (%)		Bulk Density (g/cm^3)
			%Wb	%Db	
1	689	576	16.4	19.62	1.43
2	700	585	16.43	19.66	1.45
3	703	592	15.88	18.75	1.47
4	694	579	16.57	19.86	1.44
5	697	589	15.49	18.34	1.46
Average	**696.6**	**584.2**	**16.15**	**19.25**	**1.45**
S.D	**5.41**	**6.69**	**0.45**	**0.66**	**0.02**

Effective Field Capacity and Field Efficiency of the Row Planter

The field capacity and field efficiency was calculated for planter using standard methodology described earlier and results are presented in table 6. The theoretical field capacity was determined as 0.137 ha/h, whereas the actual field capacity of planter was found to be 0.112 ha/h. From the actual and theoretical field capacity the field efficiency of the four row animal drawn row planter was found to be 81.95%. Generally, this shows that the row planter can sow a hectare of land within 8 to 9 working hours depending on the speed of operations.

Table 6: Field performance test results

No. plot	Operating Speed (km/h)	TFC (ha/h)	EFC (ha/h)	Field efficiency (%)
1	1.71	0.137	0.111	81.02
2	1.73	0.138	0.114	82.61
3	1.69	0.135	0.111	82.22
Average	**1.71**	**0.137**	**0.112**	**81.95**

Plant Population Count

Plant population count was carried out in the field after twenty days of seeding; number of seeds germinated per 1m^2 area was counted as shown in table 7. However, there was some deviation of seeds emergence at the field as compared to the recommended seed emergence, these variations might be due to environmental factors.

Table 7: Seed germination potential obtained at field test

Replication	Field germination count Per 1m^2		
	Expected	Counted	% Germinated
1	320	310	96.88
2	320	316	98.75
3	320	315	98.44
4	320	312	97.50
5	320	318	99.37
Average	**320**	**314.2**	**98.19**

Cost Analysis

The cost of operation of the machine per hour as well as per ha is presented in table 8. The annual use of the row planter was taken only 240 hr/year. The unit cost of the developed four row animal drawn row planter was determined by calculating the cost of different components and their fabrication cost. The estimated cost of the developed animal drawn row planter was determined as 5893.3 Birr. The fixed cost and variable costs for row planter seed driller are presented in table 8. In this study, manual drilling required 12 man-days to seed drill one hectare of wheat field. Considering 400Birr per day hire of pair of oxen with operator and 150birr per day for manual seed and fertilizer drilling wage, hence 3400 birr/ha was required for manual seed drilling, whereas 832.23 birr/ha was calculated for row planter (table 8).

Net savings per hectare area 2,567.77Birr/ha could be saved as compared row planter against manual seed drilling. This net saving comes because of higher field capacity of row planter than manual seed drilling.

Table 8: Operational cost of row planter and hand drilling

Cost of row planter	**5,893.3Birr**
Fixed cost	
Deprecation	2.21 Birr/hr
Interest on investment/h @ 15% per hour	2.03 Birr/hr
Tax, Insurance and Shelter (@ 2.5% of initial cost per hour	0.61
Total fixed cost/hour	4.85 Birr/hr
Variable/Operational cost	
Maintenance cost (@ 3.5% of initial cost per hour)	0.86 Birr/hr
Hire of oxen with operator per hour	50
Wage of two assistance operator per hour	37.50 Birr/hr
Total operation cost per hour	88.36 Birr/hr
Total cost /hr (Fixed cost + operational cost)	93.21 Birr/hr
Operational cost/ha	832.23 Birr/ha

CONCLUSIONS

Based on the findings of the overall performance of the redesigned row planter, it was found best as compared to previous row planters and sowing behind the plough. Modification made in the seed cum fertilizer applicator resulted proper dropping of seeds in furrows with satisfactory seed placement with covering by soil. In general, the performance evaluations indicated that the planter can be used successfully and the cost of the developed row planter is within the buying capacity of the small farmers. Hence, it can be concluded that the developed row planter's overall performance is satisfactory and recommended for large demonstration.

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