Fabrication and Evaluation of Tractor Drawn Wheat Row Planter

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Abstract- *A tractor drawn wheat row planter was fabricated in Asella Agricultural Engineering Research Center workshop and evaluated at Munesa woreda of Oromia region at farmer's field level. The project was undertaken due to the fact that most of the imported planters usually have maintenance problems in addition to high costs of procurement that are not affordable to an average farmer. Calibration of planter for wheat seeds and granular fertilizer (DAP) was carried out. The average seed rate under laboratory testing of evaluated row planter for wheat (Shorima variety) and fertilizer (DAP) were found to be 116.18 and 99.58 kg/ha respectively. The performances of row planter were evaluated in terms of seed rate, depth of planting, plant population, plant distribution uniformity, field capacity and field efficiency. The mean speed of operation, field capacity and field efficiency were found to be 2.31 km/hr, 0.36 ha/hr and 85.71% respectively. Based on the performance evaluation results, fabricated row planter can be efficiently and effectively used by the farmers.*

Keywords: - Fertilizer hoper, furrow opener, metering unit, seed hoper, seed rate.

1. INTRODUCTION

Wheat is one of the major food crops and the second important cereal crops with annual production of about 4.54 million tons cultivated on an area of 1.696 million hectares in Ethiopia (CSA, 2013). Based on CSA (2013) data, wheat occupied about 15.63% of the total cereal area with an average national yield of 2.67 t/ ha. This is low compared to the world average of 4 t/ha (FAO, 2009).

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 (Salokhe and Oida, 2003). With the present day advanced agronomic practices, seed genetics and on- farm technology to deliver optimal yield while using fewer resources, row planting is significant factor.

One of the major constraints is availability of row planting machines to meet timeliness and precision needs. The most important factors to increase production are the seed germination distribution uniformity at proper depth. These results in a better crop stand there by increasing the crop yield (Behera *et al.*, 1995). In order to increase the productivity, efforts have been made through row sowing systems.

In wheat belt zones of Ethiopia, manual row planting is becoming common practice back five to six years. Even though this practice shows yield increment compared to broad casting there is hard ship. Manual method of seed planting, results in low seed placement, spacing efficiencies and serious back ache for the farmer which limits the size of field that can be planted. Dominantly Arsi, West Arsi and Bale zone areas are known with mechanized farming system. Some farmers have tractors for tillage operation but there is small or no tractor driven row planting machine due to high importing cost. Therefore, to fill this gap we have planned to fabricate and evaluate the tractor mounted row planting machine with less cost than imported one by having the following objective:-

- To fabricate evaluate the performance of tractor mounted wheat row planter.

2. MATERIALS AND METHODS

Fabrication of tractor mounted row planter was done at Asella Agricultural Engineering Research Center workshop. Field evaluation was carried out at model farmer's field of Munessa woreda.

2.1. Material Selection

Selections of proper materials used for manufacturing of various components of row planter were done based on components of imported row planter and locally available materials. The economic consideration and availability of materials were also taken into account.

2.2. Description of the Machine

The fabricated tractor mounted row planter could have components like main frame, metering flute, hopper, ground wheel, delivery tube and furrow opener as shown in figure 1.

Figure 1. Fabricated tractor mounted row planter

2.2.1. Frame

It was constructed from 8 mm mild steel square pipe welded together to form a rectangular chassis. The top of the frame carries the seed and fertilizer hopper while the front provides hitching points for attachment to the tractor.

2.2.2. Hopper

Trapezoidal shape of seed and fertilizer hoper was fabricated from 2 mm mild steel sheet metal. The seeds and fertilizer flow freely by gravitational force into flute metering mechanism at the bottom of the hopper from its own compartment.

2.2.3. Seed and fertilizer metering mechanisms

Metering mechanism comprises metering flutes used to meter the seed and fertilizer at predetermined controlled seed and fertilizer rate. The seed and fertilizer rate uniformity achieved by parameters such as exposed length of metering flute, size of slot, shape of slot, number of slot and physical properties of the seeds.

2.2.4. Seed and fertilizer delivery tube

The seed and fertilizer delivery tubes was made from pressurized water pipe and linked to the flute house from which the seeds and fertilizer drop into the furrow.

2.2.5. Furrow openers

The furrow opener penetrates into the soil to create furrows for the fertilizer and wheat seeds placement.

2.2.6. Metering ground wheel

The ground wheel is an integral part of the seed metering components. A lugged ground wheel was provided to drive seed and fertilizer metering flute. The wheel is located at middle of the frame. It is made from 3 mm mild steel plate of 370 mm diameter and fitted with twelve triangular shaped lugs on the periphery in order to improve traction both on dry and muddy lands for the positive rotation under the stubble field conditions.

2.3. Physical Properties of Seed

The performance of seed metering mechanism in terms of picking, metering and dropping was influenced by the physical property of seeds. Therefore, some of physical properties of seeds such as thousand grains mass and bulk density of the seed are relevant to determine plant population uniformity. The wheat varieties of Hidase, Shorima and Ogolicho seeds were selected for the study to determine the thousand grain mass.

2.3.1. Thousand grain mass

The thousand grain mass (1000) were selected randomly and then weighed on the digital electronic weighting balance to obtain the thousand grain mass in gram from each samples.

2.3.2. Bulk density of wheat seed

The bulk density was determined by taking wheat in a graduated cylinder. The weight of the grain in the cylinder weighed by electronic digital balance and divided by volume of cylinder (Varnmakasti et al., 2007).

$$BD\,(KG/m^3) = \frac{W\,(kg)}{V\,(m^3)} \quad (1)$$

Where, BD = Bulk density in kg/m^3, W = Weight of sample in kg and V = Volume of sample in m^3

2.3.3. Calibration of metering flute exposed length

Metering mechanism is the most crucial component to regulate seed rate and uniformity of the row planting machines. As per the various research reports on seed metering mechanisms for row planting machine, fluted type is the most efficient one for seed rate and uniformity (Ozturk I.et al., 2012). Predetermined seed rate was maintained by reducing and increasing the exposed length of flute to seeds and fertilizer coming from the hopper. Calibration of the machine was conducted at station for metering the desired quantity of wheat seeds and fertilizer.

2.4. Field Performance Evaluation of the Machine

Field performance parameters measured includes time, speed, field capacity, field efficiency, planting depth, plant population, seed germination and distribution uniformity.

2.4.1. Speed of operation

To determine the tractor operation speed during planting operation, the time required for covering 122 m row length was recorded with digital stop watch. Five measurements were recorded in each plot and mean values were computed as km/hr calculated.

$$Speed\,(km/h) = \frac{Dis\tan ce(m)}{Time\,(s)}\,x\,3.6 \quad (2)$$

2.4.2. Theoretical field capacity

Theoretical field capacity of row planter is the rate of field coverage that would be obtained if the planter performing its function 100 % of the time at the rated forward speed and cover 100 % of its rated width. It is expressed as hectare per hour and determined as follows (Kepner *et al.*, 1978)

$$TFC\,(ha/hr) = \frac{W\,x\,S}{10} \quad (3)$$

Where, TFC = Theoretical Field capacity, (ha/hr); W = Effective width of implement, (m); and S = Speed of operation, (km/hr).

2.4.3. Effective field capacity

Effective field capacity of the planter was actual rate of work covered by the planter based upon the total field time and a function of rated width of the machine actually utilized and expressed as hectare per hour (Kepner *et al.*, 1978).

$$EFC\,(ha/hr) = \frac{A}{T} \quad (4)$$

Where, EFC = Effective Field capacity, (ha/hr); A = Actual area covered, ha and T = Time required to cover the area, hr

2.4.4. Field efficiency

Field efficiency is the ratio of effective field capacity to theoretical field capacity. It was determined by the following formula:-

$$FE\,(\%) = \frac{EFC}{TFC}\,x100 \quad (5)$$

Where, FE = Field efficiency (%); EFC = Effective field capacity, (ha/hr); and TFC=Theoretical field capacity, (ha/hr).

2.4.5. Fuel consumption

The fuel consumption was measured by refill method. The fuel tank of the tractor was filled at its full capacity and run at constant speed. After completion of the test plot, the fuel was refilled in the tank up to its full capacity. The quantity of refilled fuel computed to fuel consumption in litter per hour and litter per hectare.

2.5. Sowing Parameters

2.5.1. Seed rate

The seed rate was determined by taking the weight of seeds before and after sowing operation. Then subtracted the final weight of seed from initial weight of seed so that the seed rate was obtained and the results were expressed in terms of kg ha^{-1}. This was established considering the weight of seeds planted per hectare.

$$Seed\ rate\ (Kg/ha) = \frac{mass}{area\ of\ the\ plot} \quad (6)$$

2.5.2. Depth of sowing

The depth of the planter was determined by measuring with plastic scale, how deep the furrow openers could dig into the soil. The average depth of seed placement of the planter was determined by randomly measuring the depth of five sampled furrow.

2.5.3. Crop parameters

2.5.3.1. Average plant population

The average plant population was determined by counting the number of plants per square meter at six random places and the mean value was determined to represent the average plant population.

2.5.3.2. Seed germination and Distribution uniformity

Seed germination distribution uniformity indicates the variation of plants per 2 m row length among selected rows. The coefficient of variation (CV) is a mathematical term used to describe distribution uniformity.

$$CV = (stdev\ sample)\ x\ \frac{100}{Average\ sample} \quad (7)$$

Where: - CV- is Coefficient of Variation, Stdev - is standard deviation of sample data and Average sample- is arithmetic average of the sample data taken.

The interpretation of coefficient of variation is as characterized by Canadian company working on machinery research has accepted the following scale as its basis for rating distribution uniformity of seeding implements for wheat crop: CV greater than 15% unacceptable, CV between 10 and 15% acceptable, CV less than 10% very good and CV less than 5% excellent (Prairie Agricultural Machinery Institute (PAMI) Annual report, 2008 – 2009).

2.5.3.3. Potential yield

Potential yield was determined by using quadrant from 1 m^2 area. Samples were randomly taken from each plot and the seeds thoroughly separated from straw and weight of seeds were recorded and converted to kg ha^{-1}.

2.6. Experimental Design and Data Analysis

The randomized complete design (RCD) was adopted in experimental field with two treatments and six replications. Data were analyzed using GenStat 16th edition statistical software by least significant difference (LSD) at 5% level of significance.

3. Results and Discussion

The performances of both imported and fabricated tractor drawn row planter were evaluated for wheat at Munessa wereda of Oromia Region during the year 2016-2017.

3.1. Physical Properties of Seeds

The attempt was made to study the physical properties of wheat seeds varieties selected by farmers among number of varieties were Shorima, Ogolicho and Hidase.

3.1.1. Thousand grain mass and Bulk density of the seed

The thousand grain mass (TGM) and bulk density (BD) of different wheat variety was found as ranges from 29.15 to 34.82 gm, and 770.97 to 771.01 kg/m^3 respectively. The mean

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thousand grain weight of wheat was observed as 32.41g. The average value of bulk density for wheat was 770.99 kg/m3 which is a similar result was observed with (Navneet,2016 and Solomon A (2017)) with average value of bulk density for wheat determined as 768 kg/m^3 and 770.5 kg/m^3 respectively.

Table: 1. Average of Bulk density and Thousand Grain Mass

No.	Wheat Variety	TGW,gm	BD, Kg/m^3
1	Shorima	29.15 ± 0.64	771.01 ± 2.64
2	Hidse	34.82 ± 0.73	770.98 ± 2.64
3	Ogolicho	32.25 ± 0.65	770.97 2.93

3.2. Seed Metering Flute Calibration

The seed metering flute was calibrated for the desired seed rate by adjustment of the exposed length of flutes. The seed rate was increased with increasing exposed flute length.

Table 2 shows the calibration result of wheat seed at different metering exposed length of flute from 8 to 24 mm for the front five furrow openers. Agronomists recommend seed rate of 100 – 150 kg/ha for row planted wheat based on crop management intensity. Therefore, 16 mm exposed flute length gave nearest values of seed rate in the range of 113.68 – 118.62 kg/ha and average value of 116.18 kg/ha was obtained which lies in the recommended range.

Table 2: Calibration of seed rate (kg/ha) at different exposed flute length

Exposed length of flute(mm)	Seed rate kg/ha							
	F1	F2	F3	F4	F5	Mean	SD	%CV
8	93.6	92.88	90.24	92.70	93.64	92.64	1.39	1.5
12	108.65	112	111.28	110.56	107.62	110.02	1.83	1.66
16	118.62	117.49	116.51	114.62	113.68	116.18	2.03	1.75
20	131.28	129.61	134.61	132.76	130.29	131.71	2.01	1.53
24	142.83	143.68	140.25	139.97	144.71	142.29	2.10	1.48

3.3. Mechanical Damage to Seed by Metering Mechanism

The Mechanical damage test was carried out for visual observations of mechanical damage due to metering mechanism were recorded for all rows during laboratory test. From table 3 damaged seeds were less than 1% which is within acceptable limit. Similar results were reported by Senger et al., (2011).

Table: 3. Mechanical damage to wheat seeds by planter

No.	Total weight of Sample (gm)	Weight of broken seeds (gm)	Damaged seeds (%)
1	500	0.051	0.0102
2	500	0,062	0.0124
3	500	0.061	0.0122
4	500	0.045	0.009
5	500	0.051	0.0102
6	500	0.049	0.0098
Average	500	0.053	0.0106

Seeds collected in 15 metering wheel revolution of Shorima wheat variety.

3.4. Calibration of Metering Flute for Fertilizer

The optimum fertilizer application rate (99.58 kg/ha) was found with 12 mm exposed flute length. Table 4 indicates the observed fertilizer application rate among the front five rows (Furrow openers). It was observed that the entire samples collected for same exposed flute length were nearly same and there was little deviation among the rows i.e. (0.29 - 1.21). The CV was about in the range of (0.27 - 1.03). 12 mm exposed flute length is best suited for the recommended DAP fertilizer (100 kg/ha) application rate.

Table 4: Calibration of fertilizer application rate (kg/ha) for different furrow openers

Exp. flute length (mm)	Fertilizer application rate (kg/ha)							
	F1	F2	F3	F4	F5	Mean	SD	%CV
8	81.05	82	80.97	79.67	80.73	80.88	0.83	1.03
10	91.08	90.75	89.81	90.57	91.03	90.65	0.51	0.56
12	100.07	98.92	100.19	99.74	98.99	99.58	0.60	0.60
14	109.14	108.51	109.01	109.05	108.59	108.86	0.29	0.27
16	116.98	118.92	119.78	118.52	120.01	118.84	1.21	1.02

3.5. Machine and Operational Parameters

The field evaluation parameters which include total time required for operation, speed of operation, effective field capacity, theoretical field capacity, field efficiency, time loss for turning and adjustments and fuel consumption were measured to assess the performance of seed drills.

3.5.1. Field capacity and field efficiency

Field performance evaluations were carried out to obtain actual data on overall performance of the two tractor mounted row planters. The field capacity and field efficiency was calculated for planters using standard procedure described earlier and results are presented in Table 5. The theoretical field capacity was determined as 0.42 ha/hr for both row planters, whereas the actual field capacity of the two planter was found 0.37 and 0.36 ha/hr respectively for imported and adapted row planter. From the actual and theoretical field capacity the field efficiency of the row planter was found 88.10 and 85.71%.

Table 5: Field capacity and efficiency of the two tractor drawn row planters

Planter type	Operating speed (km/hr)	TFC (ha/hr)	AFC (ha/hr)	Field efficiency (%)
Imported	2.40	0.42	0.37	88.10
Fabricated	2.40	0.42	0.36	85.71

3.5.2. Fuel consumption

The fuel consumption measurement obtained result shown that when the operating speed increased the fuel consumption rate also increased. During operation, fuel consumption was observed as 1.42 and 1.49 l/hr at the speed of 2.40 km/hr, respectively for imported and fabricated row planter.

3.6. Sowing Parameters of Row Planters

The sowing parameters include seed rate and depth of sowing were measured and noted to assess the performance of seed drills. Agronomists, recommended seed rate and average depth of wheat seed sowing was 100-150 kg ha^{-1} and 5-7cm respectively based on crop management passion.

Table 6: Sowing parameters of seed drills for wheat seeds

No.	Types of row planter	Seed rate obtained, kg ha^{-1}	Average depth of sowing, cm
1	Imported row planter	118.45	5.8
2	Fabricated row planter	126.72	5.73

3.6.1. Depth of seed placement

The depth of seed placement in the field was observed that 5.8 and 5.73 cm respectively for imported and fabricated row planter. The depth of placement of seeds was adjusted by raising or lowering the furrow opener.

3.6.2. Seed rate

The lowest seed rate obtained in the field was observed as 118.45 kg ha^{-1}with an average seed placing of 5.8 cm for imported row planter whereas highest seed rate obtained was found to be 126.72 kg ha^{-1} with an average seed placing of 5.73 cm for fabricated row planter. The seed rates obtained in the field were within the range of recommended seed rate of wheat.

3.7. Crop parameters

The crop parameters included average plant population per m^2, seed germination distribution uniformity and potential yield were measured and noted to assess the performance of the row planter.

3.7.1. Plant population

The numbers of plants per m^2 at five random places were counted and the mean value was determined to represent the average plant population. The analysis of variance (ANOVA) revealed that the planter type had no significant effect ($p > 0.05$) on plant population. Table 7 shows the effect of planter type on mean plant population.

Table 7. Effect of row planter type on plant population (PP)

Parameter	Source of variation			Measure of differences		
	Replicati	Row planter type				
		Imported	Fabricated	LSD	SE(	%c

	on	row planter	row planter	(5%)	M)	v
Plant population	1	162.0^{c}	168.3^{b}	15.91	5.16	5.4
	2	159.3^{c}	167.3^{b}			
	3	156.3^{cd}	173.7^{a}			

Means followed by the same letter (or letters) do not have significant difference at 5% level of probability.

3.7.2. Distribution uniformity

Distribution uniformity indicates the variation in plant distribution uniformity between rows. The analysis of variance (ANOVA) revealed that the planter type had no significant effect ($p > 0.05$) on plant distribution uniformity. Table 8 shows the effect of planter type on mean plant distribution uniformity. Coefficient of variation (5.3%) of the two row planter shows that, the variation in plant distribution uniformity within acceptable limit. According to PAMI, it is in the range of *very good ranks*.

Table 8. Effect of row planter type on plant distribution uniformity (DU)

Parameter	Source of variation			Measure of differences		
	Replication	Row planter type				
		Imported row planter	Fabricated row planter	LSD (5%)	SE(M)	%cv
Plant population distribution uniformity	1	32.33^{c}	34.00^{b}	3.110	1.009	5.3
	2	32.00^{c}	33.33^{b}			
	3	31.67^{c}	35.67^{a}			

Means followed by the same letter (or letters) do not have significant difference at 5% level of probability.

Figure 2. Plant population count and visit

3.7.3. Potential yield

Potential yield was determined from 1 m^2 area. Five random observations were taken from each plot and the seeds were thoroughly separated from straw and weight of seeds were recorded and expressed in kg ha^{-1}. The analysis of variance (ANOVA) revealed that the planter type had no significant effect ($p > 0.05$) on potential yield. Table 9 show the effect of planter type on mean potential yield.

Table 9. Effect of row planter type on potential yield (PY)

Parameter	Source of variation			Measure of differences		
	Replication	Row planter type				
		Imported row planter	Fabricated row planter	LSD (5%)	SE (M)	% cv
Potential yield	1	74.9^{a}	78.7^{a}	12.98	4.21	9.8
	2	73.9^{a}	74.8^{a}			
	3	77.6^{a}	75.8^{a}			

Means followed by the same letter (or letters) do not have significant difference at 5% level of probability.

3.8. Conclusion

It was imagined that mechanizing the row planting operation could displace labour force and which could be used in other productive activities that could lead to increased productivity and can solve labourer scarcity to a large extent. The fabricated nine row tractor mounted wheat row planter worked satisfactory in actual field condition. Mass production and distribution for the farmers has to be facilitated in order for import substitution and foreign currency reduction.

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