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Research Article

Adaptation and Performance Evaluation of Tractor Drawn Raised Bed Wheat Row Planter

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Abstract

An integrated tractor-drawn wheat and fertilizer planter was fabricated in Jimma Agricultural Engineering Research Center workshop and evaluated at Omo Nadda district of Oromia region at a farmer's field. The experiment was conducted to develop and evaluate the performance of a planter capable of sowing seeds and applying fertilizer at predetermined row spacing and depths. The developed planter consisted of a frame, seed hopper, seed metering devices, seed tube, and adjustable furrow opener. The performances were evaluated in terms of seed and fertilizer rate, row spacing, depth, field capacity, field efficiency, labor cost, and economics of owning and operating. Randomized complete block design with each of three levels speeds (3, 4, and 5 km/hr) hopper fill ($H_{0.5}$, $H_{0.75}$, and $H_{1)}$ was used. There were no mechanical seeds damaged by the planter at all speed and it indicated that there was no reduction in percent germination of the seeds when compared with the recommended germination percentage. The seed and fertilizer rate was calibrated at 125 kg/ha and 150 kg/ha respectively for 20 cm row spacing and 5 cm depth as per wheat agronomic requirement. The planter was evaluated at speeds of 3, 4, and 5 km/hr and hopper filling levels of $H_{0.5}$, $H_{0.75}$, and H_1. Both forward speed and hopper filling had a significant effect on seed and fertilizer rate at $p < 0.05$. The mean effective field capacity, field efficiency, and fuel consumption were 0.45 ha/hr, 91.84%, and 2.95 l/hr at a speed of 3 km/hr. Based on the performance evaluation results, it is concluded that the developed planter can be efficiently, effectively, and economically used by the farmers.

Keywords

Capacity, Efficiency, Fertilizer, Filling, Seed

1. Introduction

In Ethiopia, wheat is one of the major food crops. In 2021/22, Ethiopia produced a total of 6.7 million MT of wheat from a total area of 2.1 million hectares (ha), of which 1.7 million ha were rainfed and 0.4 million ha were irrigated. The average productivity of rain-fed wheat was 3.0 MT/ha, while the average productivity of irrigated wheat was 4.0 MT/ha. Rain-fed wheat production in Ethiopia primarily takes place during the main rainy season, known as the Mehere (main) season from June to October in the highlands. On the other hand, irrigated wheat production takes place from November to April in the lowlands, specifically along the Awash, Wabe Shebele, and Omo River basins [14].

Currently, Ethiopia is the leading wheat consumer in sub-Saharan Africa with an annual consumption of an estimated 97 million quintals (9.7 MT). The current production levels are the result of an 18% increase in the sown area, mainly

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dominated by irrigated wheat cultivation, which reached 2.3 million ha against 1.9 million ha previously [13]. To achieve self-sufficiency and become a net exporter by 2025/26, the GoE developed the National Wheat Flagship Program for wheat self-sufficiency and import substitution. The program is designed to expand and promote irrigated wheat production on a total area of one million hectares in the 2022/23 season and expand it by 5- 10% annually [14]. According to the United States Department of Agriculture (USDA), Ethiopia’s wheat production has increased between 2013 and 2023 in area, production, and yield.

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 [10]. With the present-day advanced agronomic practices, seed genetics, and on-farm technology to deliver optimal yield while using fewer resources, row planting is a significant factor. One of the major constraints is the availability of row planting machines to meet timeliness and precision needs. The most important factor to increase production is the seed germination distribution uniformity at proper depth. These results in a better crop stand thereby increasing the crop yield [3]. To increase the productivity, efforts have been made through row-sowing systems.

One of the major constraints is the availability of row planting machines to meet timeliness and precision needs. The most important factor to increase production is the seed germination distribution uniformity at proper depth. To increase productivity, efforts have been made through row-sowing systems. Manual row planting is become a common practice for a decade. Even though this practice shows yield increment compared to broadcasting operations, it is difficult.

The manual method of seed planting results in low seed placement, spacing efficiencies, and serious backache for the farmer which limits the size of the field that can be planted. Some farmers have tractors for tillage operation but there are small or no tractor-driven row planting machines due to high importing costs. To fill this gap, Asella Agricultural Engineering Research Center developed different wheat row planters to increase the production of the sector. Therefore, this project was planned to adapt and evaluate the raised bed tractor-mounted planter with less cost than imported.

2. Materials and Methods

2.1. Description of the Study Area

The planter was fabricated at Jimma Agricultural Engineering Research Center workshop, Oromia Agricultural Research Institute (OARI), Ethiopia. The center is located at 7° 18′N and 8° 56′N latitudes and 35° 52′E and 37° 37′E longitudes, having an elevation of 1772 meters above sea level.

2.2. Materials

The selected materials used for fabricating the components of the planter are; different types of sheet metals, angle irons, square pipe, bolts and nuts, bearings, chains, etc.

2.3. Methods

2.3.1. Descriptions of the Machine

The fabricated tractor-mounted row planter has components like a mainframe, metering flute, hopper, delivery tube, and furrow opener as shown in Figure 1.

Figure 1. *The photo was taken during the machine test.*

2.3.2. 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.

2.3.3. Hopper

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

2.3.4. Seed and Fertilizer Metering Mechanisms

The metering mechanism comprises metering flutes used to meter the seed and fertilizer at a predetermined controlled seed and fertilizer rate..

2.3.5. Seed and Fertilizer Delivery Tube

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

2.3.6. Furrow Openers

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

2.3.7. Metering Ground Wheel

It is made from a 3 mm mild steel plate of 370 mm diameter and fitted with twelve triangular-shaped lugs on the periphery to improve traction both on dry and muddy lands for positive rotation under stubble field conditions.

2.3.8. Design of the Major Components

(i). Design of Frame

A mild steel angle bar having a square-shaped cross-section (welded together at ends) was selected for the frame. The frame members were welded together at the ends since; a fixed-type end connection was selected. Euler's theory for the crippling and buckling load (p_{cr}) under various end conditions is given by the equation below [5].

$$p_{cr} = \frac{\pi^2 EI}{(L_e/r)^2}$$

Where: E = modulus of elasticity for the mild steel material (E= 210 GP; A = cross-section area for a hollow rectangular shape, cm^2; p_{cr} = Euler's critical load, N; L_e= effective length of the frame, cm; r = radius of gyration of the cross-section; and I= polar moment of the cross-section.

Assuming, σ_y = 250 MPa and comparing the critical load of the frame with yield strength, whether the frame is saved or not. From the available data, the dimension of the frame was determined as.

$$\frac{Le}{r} = \pi \times \sqrt{\frac{E}{\sigma_y}}$$

The crushing stress is given by $\sigma_{cr} = \frac{\pi^2 E}{\left(\frac{Le}{r}\right)^2}$

The critical load is found as: $P_{cr} = \frac{\pi^2 EI}{{L_e}^2} = \frac{\pi^2 \times 210\left(\frac{h^3 b}{12}\right)}{{L_e}^2}$

Comparing critical stress with the yield strength of the material, critical stress is less than the yield strength of the material ($\sigma_{cr} \ll \sigma_y$). According to Euler's theory of buckling, for slender columns, the critical buckling stress is usually lower than the yield stress. Hence, the designed frame was saved from buckling.

(ii). Design of Furrow Opener

The thickness, width, and length of the furrow opener were decided on the assumption given by [11]. The length of the inclined part of the furrow opener generally ranges from 10 to 20 cm, and the radius of curvature R < 12 cm. The minimum clearance length of the furrow opener (H_I) between the land surface and the lower edge of the frame was 20 cm. The height of the furrow opener was calculated as given below.

$$H_T = a_{max} + H_I + \Delta H = 10 + 35 + 15 = 60 \text{ cm}$$

Where; a_{max} = depth of tool, cm; H_I = length of furrow opener, cm; ΔH = length of furrow opener used for fastening with frame, cm. Load angle was determined by.

Table 1. Specific soil resistance at a depth of 15 c.

S/N	Soil Type	Specific Resistance, kg/cm^2
1.	Light	0.12
2.	Medium	0.15
3.	Heavy	0.20
4.	Very heavy	0.25

Source; Dubey (2003)

The draft force exerted on the cutting blade was determined using the following equation.

$$D = K_O \times n \times w \times d = 0.8 \times 3 \times 25 \times 30 = 360 = 3531.6 \text{ N}$$

Where, D = draft force, N; K_o= soil resistance, kg/cm^2; w= width of furrow opener, cm; d = depth of tyne, cm; n= number of furrow opener.

Finally, the total draft required for operation and each draft of the furrow opener was calculated by,

$D_t = D \times FOS \times g = 3531.6 \times 1.5 \times 9.81 = 51867.49$ N

Where, D_t= total draft, N; D = draft, N; FOS = factor of safety; g = force due to gravity, m/s^2

$$D_i = \frac{\text{Draft (N)}}{\text{number of rows}} = \frac{51867.49}{3} = 17322.5 \text{ N}$$

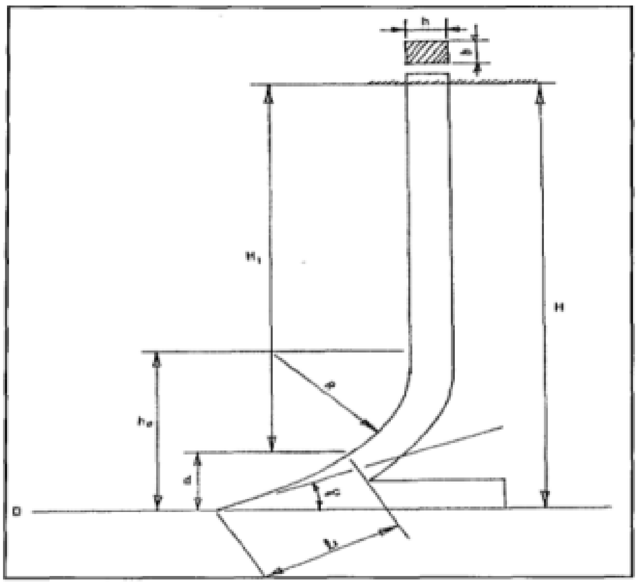

Figure 2. Schematic diagram of furrow opener.

2.4. Weight Determination of Components

To estimate the loads on every part of the integrated row planter and ridger, it was necessary to evaluate the weight of all components. Accordingly, the weights of the furrow opener, frame, cutting edge, hopper, Seed and fertilizer delivery tube, and seed metering were estimated. The total weight of the integrated row planter and ridger including the weights of the frame, three-point linkage unit, furrow opener, and the edge of cut were estimated. Taking 2% margins for welding weights, bolts, nuts, etc. Finally, the total weight of the integrated row planter and ridger was calculated to be 1480.11 N.

2.4.1. Determination of Draft

The maximum draft required to drive the furrow opener is calculated as follows.

$$D = C_{AC} \times S_R \times g \times FOS = 5400\ cm^2\ x\ 0.75\ Kg/cm^2\ x\ 9.81\ m/s^2\ x\ 1.5 = 59{,}595.75\ N$$

Where, D = Maximum draft; C_{AC}= Cross-section area of the furrows; S_R = maximum soil resistance; g = force due to gravity; FOS = Factor of safety.

2.4.2. Determination of the Power

The power required to pull the designed implement was estimated as follows [15].

$$P_d = \frac{D \times S}{1000} = \frac{59{,}595.75 \times 0.833}{1000} = 49.64\ KW = 66.57\ hp$$

Where; P_d = power required to drive the implement; D = draft required to drive a furrow opener S = speed of operation (0.833 m/s).

The power required to operate the machine was calculated as follows.

$$P = \frac{\text{Power required to drive the implement}}{\text{Coefficient of friction}} = \frac{66.57}{0.85} = 78.32\ hp$$

Where: P = power required to operate the implement; D = draft requirement of the implement; S = forward speed of the tractor.

2.5. Working Principles

The seed metering mechanism of the planter is a flute type. As the tractor moves forward the seed-metering device is rotated by a chain-sprocket arrangement through drive wheels. One operator was required to operate the machine. Seed-to-seed spacing in the field was regulated by the rate of rotation of the seed-metering plates. As the metering plate rotated i.e. the seed spacing of crops maintained.

2.6. Performance Evaluation of the Machine

Field performance parameters measured include time, speed, field capacity, field efficiency, planting depth, plant population, seed germination, and distribution uniformity. Before conducting actual tests in the lab or field, the machine was tested to confirm the workability of all the functional components and to determine and check any malfunctioning parts and defects in the manufacturing.

2.6.1. Laboratory Performance Test

(i). Mechanical Damage Test

The test for percentage seed damage was done with the planter held position, with seeds loaded into the hopper. The wheel was rotated 10 times in turns. The seed discharged from the seed tube was observed for any visible damage. The seeds visibly damaged during the calibration were identified, the total collected visibly damaged seeds were weighed and the percentage damage was calculated using the equation below as given by [9].

$$\%damage = \frac{W_s}{W_{ts}} \times 100$$

Where, W_s =weight of damaged seed; W_{ts} = Total weight of collected seeds.

(ii). Seed Distribution Test

A mark was made on the drive wheel 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 discharged seeds. The drive wheel rotated 10 times at low speed. The seed in the bag for each furrow opener after 10 revolutions was weighed on a balance collected and compared.

(iii). Seed Germination Test

This test was conducted to find out whether there was internal damage. To calculate the germination percent, known numbers of seeds were sown and after 10 days of planting, germinated seeds were counted and the percentage of germination was calculated [9].

$$Germination = \frac{N_{sg}}{N_{sp}} \times 100$$

Where, N_{sp}= Number of seed planted; N_{sg}= Number of seed germinated.

2.6.2. Field Test

The field test was conducted on well-prepared and harrowed farmland. The distribution pattern of the seeds along rows was examined to observe the seed distribution along the rows. The performance parameters to be measured were the time required (hr/ha) which was measured using a stopwatch, labor requirement, cost of planting, plant population, field efficiency, field effective capacity, and uniformity of seed distribution as well as soil parameters; soil bulk density, and moisture content of soil were determined.

Figure 3. Photo taken from the field.

(i). Moisture Content of Soil

Five samples were collected randomly from 0 to 20 cm depth of soil surface before operations from the test plots. The samples were also kept in an oven for 24 hours at a temperature of 105°C and weighed before and after drying. The moisture content (Dry basis) was determined by the following formula [9].

$$MC\ (\%) = \frac{W_s - W_d}{W_d} * 100$$

Where: Mc = Moisture content of the soil sample; Ws = Weight of the soil sample, and Wd = Weight of dry soil sample.

(ii). Bulk Density of Soil

The samples were weighed, and the dry weights of the samples were calculated with the help of moisture content (db.). The ratio of the dry weight of soil to the volume gives the bulk density. The bulk density of soil was calculated by using the following formula [6].

$$B_{ds} = \frac{W_d(g)}{V_s}$$

Where: Bds = Bulk density of soil in (g/cm^3); Wd = weight of dry soil samples (g); Vs = volume of soil in core sampler (cm^3).

(iii). Travel Reduction

The distances the tractor traveled ahead at every 10 revolutions under load and no load on the same surface were measured after a mark was created on the tractor drive wheel with colorful tapes. The speed reduction was calculated as follows [2].

$$\text{Travel reduction} = \frac{M_2 - M_1}{M_2} \times 100$$

Where, M_2= a tractor drive wheel with no load (m), M_1 = tractor drive wheel with load (m).

(iv). Theoretical Field Capacity

This is dependent on the implement's speed and potential width. It is the rate of field coverage that was reached if the implement performed its job at 100% of its rated width [4].

$$TFC = \frac{W \times S}{10}$$

Where, TFC= Theoretical field capacity, ha/h; S= Speed of operation, km/h and W= Theoretical width of implement, m.

(v). Effective Field Capacity

The machine's effective field capacity is the real rate at which it can work. This includes non-productive procedures such as turning at the field's ends to inspect the performance of a certain piece of equipment. The overall time needed to finish the procedure was determined, as well as the effective field capacity [7].

$$EFC = \frac{A}{T}$$

Where, EFC = Effective field capacity, (ha/h); A = Actual area covered, (ha) and T= Total time required to cover the area, (hr).

(vi). Field Efficiency

Field efficiency is one of the most important criteria in determining the tillage implement performance. It was calculated using the formula below [12].

$$\text{Field efficiency (\%)} = \frac{EFC}{TFC} \times 100$$

(vii). Fuel Consumption

Fuel consumption was calculated using the top-fill method. Before the test, the fuel tank was filled. The amount of fuel necessary to fill up the tank after the test is the fuel consumption for the length of the test. The observed data was used to calculate the fuel usage in liters per hour using the equation below [7].

$$Fc = \frac{f_r}{t}$$

Where: Fc =fuel consumption (l/hr); f_r =Re-filled quantity of fuel (l); t =Total time taken (hr).

2.6.3. Sowing Parameters

(i). Seed Rate

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

$$\text{Seed rate (Kg/ha)} = \frac{\text{mass}}{\text{Area of the plot}}$$

(ii). Depth of Sowing

The depth of the planter was determined by measuring with a plastic scale how deep the furrow openers were dug into the soil. The average depth of seed placement of the planter was determined by randomly measuring the depth of five sampled furrows.

2.6.4. Crop Parameters

(i). 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.

(ii). Seed Germination and Distribution Uniformity

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

$$CV = \text{Seed rate} * \frac{100}{\text{Average sample}}$$

Where, CV- is the Coefficient of variation, and Average sample- is the arithmetic average of the sample data to be collected.

2.7. Experimental Design and Data Analysis

The experiment was arranged in a Randomized Complete Block Design (RCBD) with two treatments and three replications. Data were analyzed using R software by least significant difference (LSD) at a 5% level of significance.

2.8. Cost Evaluation of the Machine

The cost of an adapted raised bed planter was considered under two heads known, as fixed costs and variable costs. The estimation of annual and hourly operational costs of the machine was based on the capital cost, interest on capital, cost of repairs and spare parts, labor cost, fuel cost, and depreciation.

3. Results and Discussion

The results of the experiments conducted in the field for the performance evaluation of implements based on field and operations results are discussed in this chapter. The analysis of data and interpretation of results obtained during the field performance evaluation and other treatments are discussed.

3.1. Laboratory Test

3.1.1. Seed Calibration Test

The adapted wheat planter was calibrated before actual data collection to determine the actual seed and fertilizer rate of the planter and to see variations in the rates among furrow openers. Table 3 and Table 4 show that the weights of seeds and fertilizers collected from each furrow opener varied from 125.52 to 126.71 kg/ha, and 152. 87 to 153.94 kg/ha, respectively. It can be seen that there was no remarkable coefficient of variation of seed and fertilizer rate among the furrow opener which ranged from 0.43 to 0.64% and 0.45 to 0.62%respectively.

Table 2. Calibrations of seed rate (kg/ha) for each furrow.

Weight of seed dropped per seed tube (gm)										
F_1	**F_2**	**F_3**	**F_4**	**F_5**	**F_6**	**Total seed (gm)**	**Mean**	**SD**	**CV**	**Seed rate (kg/ha)**
54.86	54.74	55.48	55.30	55.60	55.26	331.24	55.21	0.34	0.62	125.57
55.53	55.65	56.29	55.54	54.46	54.48	331.95	55.33	0.34	0.62	125.86
55.37	54.92	55.54	55.28	55.36	54.62	331.09	55.18	0.34	0.62	125.52
55.81	55.38	55.74	55.37	55.95	55.57	333.82	55.64	0.24	0.43	126.57
55.47	55.50	56.39	55.73	55.42	55.66	334.17	55.70	0.36	0.64	126.71
Average						332.45	55.41	0.32	0.59	126.05

Table 3. Calibrations of fertilizer rate (kg/ha) for each furrow.

Weight of fertilizer dropped per seed tube (gm)										
F_1	**F_2**	**F_3**	**F_4**	**F_5**	**F_6**	**Total seed (gm)**	**Mean**	**SD**	**CV**	**Seed rate (kg/ha)**
67.67	67.74	66.72	66.85	67.38	67.43	403.79	67.30	0.42	0.62	153.09
67.63	67.68	67.48	68.36	67.42	67.44	406.01	67.67	0.35	0.52	153.94
67.37	66.82	66.86	67.74	67.28	67.34	403.41	67.24	0.34	0.51	152.96
67.19	67.48	66.92	67.44	67.38	66.76	403.17	67.20	0.30	0.45	152.87
67.28	67.78	67.47	67.48	66.80	67.68	404.49	67.42	0.35	0.52	153.37
Average						404.17	67.37	0.35	0.52	153.25

3.1.2. Mechanical Damage Test

Table 4 shows that there was no visual damage to the seeds at all the selected speeds. Moreover, the seed germination test after the metering of seeds was conducted and 100 seeds were sown in a petri dish and found that no seed damage was observed. Average germination (95.67%) was observed and was similar to that of the predicted seed germination by the supplier.

Table 4. Data obtained from laboratory tests of the planter.

Observations	**Speed (km/hr)**	**Seed rate obtained (kg/ha)**	**Mechanical Damage (%)**	**Germination (%)**
1	3	126.80	0.00	97.00
2	4	123.86	0.00	95.00
3	5	121.74	0.00	95.00
Average		124.13	0.00	95.67

3.1.3. Effects of Operating Speed on Seed Rate

The analysis of variance (ANOVA) revealed that the forward speed and hoper loading level had a significant effect ($p < 0.05$) on wheat seed rate, whereas the interaction of hopper loading level and forward speed had no significant effect ($p > 0.05$) on wheat seed rate. Table 5 shows the effect of speed of operation, hopper loading level, and the combined effect of speed and level of seed filling in the hopper on wheat seed rate.

Table 5. Main effects of operating speed and hopper filling on seed and fertilizer rate.

Operating Speed (km/hr)	Seed rate (kg/ha)	Fertilizer rate (kg/ha)
V_3	126.35[a]	152.75[a]
V_4	123.24[b]	148.90[b]
V_5	120.52[c]	146.93[c]
Hopper filling		
$H_{0.5}$	123.78[a]	149.90[a]
$H_{0.75}$	121.23[b]	148.70[b]
H_1	120.84[c]	146.12[c]
LSD (5%)	0.16	0.17
CV (%)	0.12	0.11

Means followed by the same letter do not have a significant difference at a 5% level of probability.

Increasing speed of operation from 3 to 5 km/hr as well as increasing hopper filling level from $H_{0.5}$ to H_1 had decreased the seed rates. However, the combination of operational speed and hopper filling capacity did not have a significant effect on seed rates.

The highest seed rate of 125.81 kg/ha was recorded at a forward speed of 3 km/hr and half hopper loading capacity. Whereas the lowest seed rate of 118.86 kg/ha was obtained at the speed of 5 km/hr and full hopper loading capacity. This indicated that forward speeds greater than 5 km/hr would result in less seed rate. Forward speeds less than 3 km/hr would result in a greater seed rate, which exceeds the recommended 125 kg/ha of wheat seeds.

3.1.4. Effects of Operating Speed on Fertilizer Rate

The analysis of variance (ANOVA) revealed that the forward speed and hopper loading level had a significant effect ($p < 0.05$) on fertilizer rate, whereas the combination of hopper loading level and forward speed had no significant effect ($p > 0.05$) on fertilizer application rate. Table 6 shows the effect of speed of operation, hopper loading level, and the combined effect on fertilizer rate. Table 6. Effects of operating speed and hopper filling level on fertilizer application rate.

Table 6. Effect of operating speed on fertilizer rate.

Operating speed (km/hr)	Hopper filling	Seed rate (kg/ha)	Fertilizer rate (kg/ha)
V_3	$H_{0.5}$	125.81[a]	150.71[a]
V_3	$H_{0.75}$	125.47[b]	150.30[b]
V_3	H_1	125.37[bc]	149.96[bc]
V_4	H0.5	122.58[d]	146.79[d]
V_4	$H_{0.75}$	122.42[de]	146.50[de]
V_4	H_1	122.29[ef]	145.76[f]
V_5	$H_{0.5}$	119.88[g]	144.74[g]
V_5	$H_{0.75}$	119.66[gh]	144.50[gh]

Operating speed (km/hr)	Hopper filling	Seed rate (kg/ha)	Fertilizer rate (kg/ha)
V_5	H_1	118.86^{i}	144.20^{hi}
LSD (5%)		0.22	0.31
CV (%)		0.10	0.10

Means followed by the same letter has no significant difference

3.2. Physical Properties of Soil

3.2.1. Soil Moisture Content

The mean data on soil moisture content before operations at 0-20 cm depth was recorded and presented in Table 3. The moisture content of the soil varied from 15.20 to 16.44% with an average value of 15.82%.

3.2.2. Bulk Density

Values of bulk density before operations at 0-20 cm depth were recorded. The bulk density of the soil was found to be in the range of 1.43 g/cm^3 to 1.54 g/cm^3 with an average value of 1.49 g/cm^3.

3.2.3. Theoretical and Effective Field Capacity of Planter

The average theoretical field capacity of the planter at 3, 4, and 5 km/hr were 0.49, 0.66, and 0.82 ha/hr, respectively. Effective field capacity at different speed operations 3, 4, and 5 km/hr were found to be 0.42, 0.55, and 0.67 ha/hr respectively. Both theoretical field capacity and effective field capacity increased with an increase in speed of operation. The reason might be due to the increment of the working width of the cut and the minimum time required to complete the practical work at a higher forward speed than a lower forward speed. This observation was similar to the result obtained by [1].

Table 7. Field performance results on (20 x 30 m^2) plot.

Operating Speed, km/hr	Draft, N	Wheel slippage, %	Fuel Consumption, L/hr	TFC, ha/hr	EFC, ha/hr	FE,%
3.00	243.20	2.37	2.95	0.49	0.45	91.84
4.00	277.86	4.18	3.83	0.66	0.57	86.36
5.00	298.00	5.47	4.65	0.82	0.65	79.27

Field Efficiency

The minimum field efficiency occurred at 5 km/hr operating speed was 79.27% and the maximum field efficiency observed at a speed of 3 km/hr was 91.84%. Field efficiency decreases as speed increases. The major reason for the reduction in field efficiency by increasing forward speed was due to the less theoretical time consumed in comparison with the other test plots [9].

3.2.4. Draft Requirement and Wheel Slip

The draft required to operate the machine was calculated by empirical formula. The average values of the draft were observed as 243.20, 277.86, and 298.00 N at speeds of 3, 4, and 5 km/hr, respectively. The minimum wheel slip of 2.37% and maximum wheel slip of 5.47% were observed at speeds of 3 km/h and 5 km/h, respectively. Both draft and wheel slippage to operate the developed planter increase with the increase in the operating speed. The reason might be due to higher force requirement at a higher speed than lower speed. This observation agreed with the result reported by [8].

3.3. Economical Evaluation

Tractor drawn raised bed planter required only a single operator to operate. The time required to plant and fertilizes a hectare of land using six row tractor drawn seed drill, with one person, was 3 and half hours-ha^{-1} at speed of 5 km/hr. The time required to plant and fertilize a hectare of land using a raised bed planter was 1.54 hours-ha^{-1} at a speed of 5 km/hr. The time requirement per hectare is nearly two times less than operating with six row planter when a raised bed planter is used at 5 km/hr.

4. Conclusion and Recommendation

4.1. Conclusion

The results of the mechanical damage test indicated that there was no visual damage to the seeds at all the selected speeds.

The forward speed and hopper loading level had a significant effect ($p< 0.05$) on the seed and fertilizer rates, whereas their interaction had no significant effect ($p>0.05$) on both seed and fertilizer rates. Increasing the speed of operation from 3 to 5 km/hr and the hopper filling level from $H_{0.5}$ to H_1 decreased the seed and fertilizer application rates. However, the combination of operational speed and hopper filling level did not have a significant effect on the rates.

Forward speeds greater than 5 km/hr result in less seed rate, and forward speeds less than 3 km/hr result in greater seed rate, which was greater than the recommended 125 and 150 kg/ha of wheat seeds and fertilizer respectively.

The average theoretical field capacity of the planter at 3, 4, and 5 km/hr were 0.49, 0.66, and 0.82 ha/hr, respectively. The effective field capacity at operating speeds of 3, 4, and 5 km/hr were found to be 0.45, 0.57, and 0.65 ha/hr respectively on well-prepared seedbeds. Both theoretical and effective field capacity increased with an increase in operating speed.

4.2. Recommendations

The performance evaluations indicated that the planter can be used successfully on farms for sowing operations. The issues that must be addressed to make the planter popular, adaptable, and usable among the farmers were drawn as follows.

The adapted planter can be used for wheat sowing on well-prepared seedbeds.

Abbreviations

ANOVA	Analysis of Variance
BD	Bulk Density
CV	Coefficient of Variance
DB	Dry Basis
EFC	Effective Field Capacity
LSD	Least Significant Difference
MC	Moisture Content
OARI	Oromia Agricultural Research Institute
RCBD	Randomized Complete Block Design
SR	Seed Rate
TFC	Theoretical Field Capacity

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Conflicts of Interest

The authors declares no conflicts of interest.

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