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Modification and Performance Evaluation of AAERC Tractor Drawn Wheat seed drill

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ABSTRACT

A large number of tractors with 60 to 180 horsepower have been distributed to farmers to increase farm mechanization and enable increases in crop yield. To boost crop yield at the farm level, agricultural tools and equipment like tractor-drawn seed drill is crucial in combination with these tractors. Therefore, by increasing of seed drill's size, the developed tractor-drawn wheat seed drill can be made more suitable for all tractors, increasing both the machine's capacity and efficiency. This experiment was conducted to design, construct and assess the performance of a prototype wheat seed drill proficient of sowing wheat seeds and fertilizer is applied according to predetermined row spacing and depths. A frame, a seed hopper, seed measuring tools, a seed tube/spout, an adjustable furrow opener, and drive wheels were included in the development of the seed drill machine. The effectiveness has been assessed in relation to the rate of seed and fertilizer, row spacing, seed placement depth, number of plants/stand, field capacity, field efficiency, labor cost, ownership, and operating expenses. A randomized complete block design was employed for the experiment, with three replications, three hopper fill levels, and three operating speeds. There were no Percent of visible and invisible mechanically seed damaged by the seed drill for at all speed and it indicated that there was no decrease in percent sprouting of the seeds when compared with germination percentage of the seed recommended by seed supplier. The fertilizer and seed rates were calibrated at 125 and 150 kg/ha, respectively, for row spacing of 20 cm and 5 cm depth as per wheat agronomic requirement. The machine has been assessed at speed of operation of 3, 4, and 5 km/hr, with hopper filling levels of H_{50}, H_{75}, and H_{100}. Both hopper filling level and forward speed of the seed drill had significant influence on fertilizer and seed rate at $p < 0.05$. Therefore, the optimal operating speed should be restricted to no more than 3 km/hr. The average field capacity, field efficiency, and fuel consumption were 0.44 ha/hr, 89.1% and 3.6 l/hr at speed of 4 km/hr. Based on the performance evaluation findings, it concludes that farmers can utilize the developed seed drill to sow wheat efficiently, effectively, and economically.

Keywords: Development; Fertilizer; Field capacity; Field efficiency; Fuel consumption; Germination; Mechanization; Prototype; Speed; Wheat.

1. Introduction

1.1. Background

Cereals, pulses, and oilseeds are Ethiopia's main crop categories. These crops not only provide the majority of the nation's food needs, but they also generate money for households and contribute to the nation's foreign exchange profits (Hussain *et al.*, 2002).

According to the Meher Season Post-harvest Crop Production Survey results for the year 2021/22, grain crops (cereals, pulses, and oilseeds) covered a total land area of approximately 12,196,548.67 hectares. From these crops, a total volume of approximately 327,903,521.41 quintals of grains were obtained from private peasant holdings. Cereals are the main food crops that fall under the category of grain crops. Cereals occupied 81.97% (9,997,511.08 hectares) of the total area used for grain crops. 15.31%, or 1,867,047.71 hectares, of the grain crop area were made up of wheat. 88.69 % (or roughly 290,808,263.25 quintals) of the grain production came from cereals, with wheat accounting for 17.71% (or 58,078,220.52 quintals) of that total (CSA, 2021).

One-third of the world's population depends on wheat, one of the most significant cereal crops (Hussain et al., 2002).The majority of sub-Saharan Africa's wheat production comes from Ethiopia. In terms of area covered, wheat comes in third place behind teff and maize and in terms of total yield and productivity, and second following to maize (Zea mays). Approximately 1.8 million hectares are planted to wheat each year (CSA, 2021), with the Bale, Arsi, and Shewa highlands accounting for 75.50 percent of the present total area used for wheat cultivation.

Even though wheat is the main crop that feeds the great majority of the nation's people, the yield per hectare is very low when compared to other wheat-producing nations globally.

The crop's low productivity and production can be ascribed to a number of factors, including a reliance on rainfall, outdated farming methods, and a lack of utilization of new biological and mechanical farm inputs. The primary cause of the low production level in the nation is the inefficiency of the old farming system. Aware of this, initiatives have been made to increase wheat yield and production through the extension system.

Increased production requires the prompt and regular establishment of optimal plant populations. Manual row planting is difficult, results in poor seed placement and spacing efficiency, and causes substantial back strain for farmers. This is because thorough hand measuring of seeds takes longer and limits the amount of land that can be planted in rows (Kalay & Moses, 2017).

To modernize Ethiopia's wheat production, Melkasa, Asella, and Jimma, attempted to create and adapt an animal-drawn wheat seed drill for dealing with challenges connected to the establishment of the optimum plant population with different design techniques.

Animal-drawn wheat seed drill driven was produced at AAERC. It had a fluted metering mechanism and could plant four rows at once with 0.12ha/hr of actual field capacity. While the practical test, three defects have been identified on the machine: heavyweight, misaligned chain during flute exposed length adjustment, and seed breakage. These days, it is modified to have a single shaft that rotates the ground wheel and metering mechanism simultaneously. The issue with this modified seed drill is that it must hold up the driver wheel while turning, which can make the operations somewhat laborious (Ashebir Tsegaye & Abayineh Awigichew, 2023).

A six-row animal-drawn wheat seed drill has also been developed and demonstrated by the Melkasa Agricultural Research Center. With this seeder, wheat can be planted at a seed rate of 125–150 kg/ha. Its coverage width is 1.2 meters. The current state of animal-drawn wheat seed drills is generally characterized by its inability to maintain a consistent seeding rate and even seed delivery due to defects in design and manufacturing.

Moreover, more advanced foreign tractor-drawn wheat seed drills that can plant eight to twenty-four rows at a time are also accessible in the markets. The majority of these devices are made to plant fertilizer-mixed seed in an opened furrow. Because power is transferred via a chain and sprocket system with numerous rotating shafts, the design of these devices is intricate. However, the majority of farmers find it difficult to afford these machines because of their high prices. Consequently, it is imperative to develop tractor-drawn seed drills using reasonably priced, locally sourced materials as an import substitution.

To address these issues, a tractor-drawn wheat seed drill with six rows was created and tested for a master's thesis project. Subsequently, mini tractors were used at the AAERC for on-farm evaluation, yielding an effective field capacity of 0.33, 0.43, and 0.5 ha/hr at 3, 4, and 5 km/hr, correspondingly. Additionally, it was discovered that the seed drill's field efficiency at the same level of operation speed was 88.82, 85.93, and 81.69, respectively (Abulasan K., 2023). But in an effort to increase farm mechanization and enable increases in crop yield, the government has recently given farmers access to a large number of tractors ranging in power from 60 to 180 horsepower. Hence, agricultural tools and equipment like tractor-drawn seed drills will be crucial in conjunction with these tractors. Therefore, by increasing the planter's size, the developed tractor-drawn wheat planter can be made more compatible with all tractors, enhancing both the machine's field capacity and field efficiency.

This research project is being restarted with the intention of enhancing the previously produced tractor-drawn wheat seed drill and increasing its field capacity, considering the following desired

1.2. Study Objectives

1. To modify the developed tractor drawn wheat seed drill.

2. To evaluate the performance of the modified machine.

░ 2. Materials and Methods

2.1. Descriptions of Machine

The developed wheat seed drill is made up of the following components: ground wheel, covering device, metering device (fluted roller), hitching system, spout and tubes for delivering seed and fertilizer, seed and fertilizer hoppers, furrow openers, and power transmission shaft.

Figure 1. Modified prototype of wheat seed drill

2.1.1. Frame

The main frame is the seed drill's skeleton structure, upon which all other components are mounted. Weight and strength were the two design considerations addressed while deciding on the material necessary for the frame to be constructed. The induced draft might cause the frame to twist and bend because the hopper, hitch attachment, drive wheel unit, seeds, and furrow openers are fixed to it. A 40 mm by 40 mm mild steel square hollow piece with a 4 mm thickness was used to give the necessary strength.

2.1.2. Hitching System Design

A three-point hydraulically-controlled linkage, situated at the rear end of the tractor, served as the link between the drilling machine and the tractor. (ASAE, 1994) was used to establish the geometric measurements for the mast height, lower hitch point span, mast, and linch pin hole distance.

2.1.3. Seed and Fertilizer Hopper

Mild steel sheet metal with a 1.50 mm thickness was utilized to construct the seed and fertilizer hopper. This material is easily obtained and reasonably priced. Additionally, the seed hopper features a lid with a handle to make opening it easier. Therefore, the hopper was trapezoidal in the lower half and rectangular in the top half (1647 mm x 380 mm x 150 mm) for the trapezoidal and rectangular portions of the hopper, respectively. Throughout its length, the hopper was separated into two sections: one for seeds and the other for fertilizer. The design of the hopper capacity took into account the seed and fertilizer rates of 125 to 150 kg/ha and 125 to 150 kg/ha, respectively. The average bulk density of 833.06 and 944.66 kg/m^3 for wheat and fertilizer respectively were considered for hopper volume determination (Abulasan, unpublished). The theoretical volume of the hopper was calculated using the following equation from (Olaoye and Bolufawi, 2001) based on the seeding rates mentioned above; as follows,

$$V = \frac{S_R}{n \times BD} \qquad \ldots(1)$$

Hence, hopper having a volume of 0.09m^3 was designed and fabricated.

Where: - S_R = seeding rate (kg/ha), n = number of refilling per hectare, BD = bulk density of the seeds (kg/ m^3).

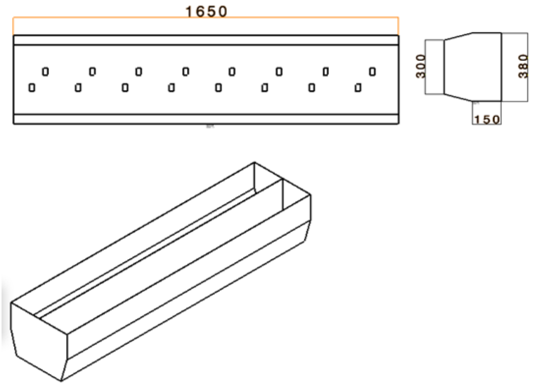

Figure 2. An isometric view of the seed and fertilizer hopper

2.1.4. Metering Devices

The fluted roller seed metering device was made of circular aluminum alloy. Twelve slots (flutes) were designed along the length of a roller having 12 mm diameter and 5 mm depth for each flute and 5 mm spacing between the flutes in accordance to (RNAM, 1991) which recommends that the number of flutes in the roller should rage from 8 - 12. When the ground wheel turns, seeds from the seed hopper fill each flute in turn. The dimensions of fluted rollers were chosen based on the physical characteristics of wheat seeds. The diameter of the fluted roller is vital in dropping the calculated quantity of seeds per unit area and is determined by the desired number of flutes and their spacing using the method below,

$$d_r = \frac{N_f\left(d_f + s_f\right)}{\pi} \qquad \ldots(2)$$

As a result, the fluted roller's diameter of 58 mm was found. Where, dr is the diameter of the fluted roller (mm), sf is the flute spacing (mm), and df is the flute diameter (mm).

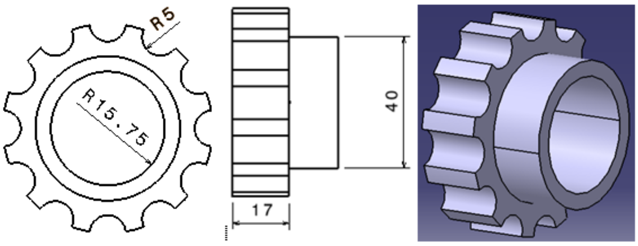

Figure 3. Isometric view of seed and fertilizer metering device

2.1.5. Adjustable furrow openers

The front side of the frame has furrow openers attached to it, which help get the soil ready for seeding. Seeds and fertilizers are deposited into the soil by boots and seed and fertilizer delivery tubes as the furrow openers split the soil. Eight bolt and nut furrow openers were mounted on the main frame of the planter. The furrow openers could be moved vertically to change the depth.

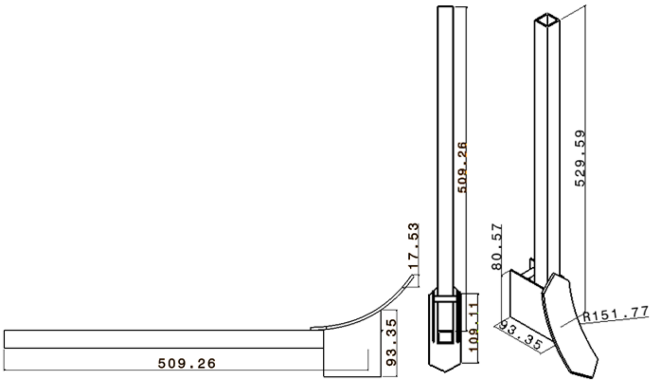

Figure 4. Schematic of diagram designed furrow opener

The following formula was used to calculate the draft force applied to the furrow opener (Kurtz, *et al*., 1984),

$$D = K_o * n * w * d \qquad \ldots(3)$$

For the purpose of computation, soil resistance K_o is horizontal and functions in the shovel's axis of symmetry. For heavy soil, 0.25 kg/cm^2 were the anticipated value.

Table 1. Specific Soil Resistances up to a Depth of 15 cm

S.No.	Soil type	Specific resistance, kg/cm^2
1	Light soil	0.12
2	Medium soil	0.15
3	Heavy soil	0.20
4	Very heavy soil	0.25

Source: Dubey, 2003.

Assuming, a = 3cm at the bottom and b= 5 cm at the top, the cross section of furrow is trapezoidal in shape d = 5 cm substituting the values in Equation 3,

$$D = 392.4\,N$$

The draft force exerted on each furrow opener was determined as follows,

$$D = 49.05\,N$$

Where, W is the opener's width (in centimeters), d is its depth (in centimeters), n is the number of furrow openers, K_o is the resistance of the particular soil, and D is the draft force (N). Nonetheless, it was found that 40 mm x 40 mm x 4 mm square hollow pipe M.S. furrow openers were reasonably safe and easily found on the market.

2.2. Determination of the Weight Parts of the Seed Drill

It needs to be determined the weight of all the component parts in order to calculate the load on each component of the wheat seed drill.

Table 2. Weight of each components of the planter

No.	Components	Quantity	Area (m^2)	Volume (m^3)	Density (kg/m^3)	Mass (kg)	Weight (N)
1	Hopper	1	0.78	7.8 x10^{-4}	7850	6.1	59.84
2	Main frame	1	0.31	5.11 x10^{-4}	7850	4	39.24
3	Fluted roller	16	0.013	4.2 x10^{-4}	2700	1.13	11.1
4	Spout	16	0.29	3.8 x10^{-4}	7850	2.98	29.23
5	Furrow opener	8	0.42	6.88 x10^{-4}	7850	5.4	52.97
6	Hitch	1	0.09	5.74 x10^{-4}	7850	5.02	49.25
7	Hopper cover	1	0.55	6.9 x10^{-4}	7850	5.42	53.2
	Total weight						**294.83**
	Weight of parts lay on the wheel shaft including 2% for bolts ,nuts and other						**300.73**
	Grain						621.8
	Fertilizer						725.1

2.2.1. Ground wheel

The ground wheel of the seed drill, which has an external diameter of 830 mm, is connected directly to the seed metering device and was designed as an integrated part of the seed metering mechanism. The mild steel sheet metal, measuring 150 mm in width and 3 mm in thickness, was used to make the wheel rim. Eight spokes, measuring 375 mm in length and 12 mm in diameter, were built for each wheel and were welded to the hub at the center of the wheel, acting as a shaft bearing or bushing, at equal intervals (Figure 5).

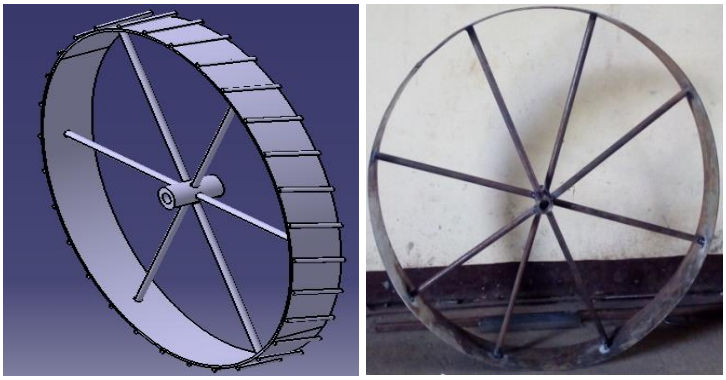

Figure 5. Isometric view of ground wheel

2.3. Determination of Force Required Driving the Planter

The rolling resistance force (F) is going to be computed using the following equation, which is considered to act horizontally at the ground and wheel contact patch or wheel and ground interface (Reece, 2002),

$$F = \left(\left(\frac{z}{d} \right)^{\frac{1}{2}} + i \right) \times N \qquad \ldots(4)$$

$$Ff = \left(\left(\frac{2cm}{83cm} \right)^{0.5} + 0.05 \right) x823.81N = 169.1N$$ Where, F_f = force required to pull the planter (N);

The variables Z and d represent the maximum allowable wheel sinkage (cm) and wheel diameter (83 cm), respectively. N represents the machine weight on each wheel, 823.81N; i is the ground gradient, let i = 5%; z is the maximum wheel sinkage depth (on a soft surface, z ≈ 0.05d = 3cm), and N is the weight of the planter on each wheel, 823.81N. As a result, the total force needed to draw the planter was calculated to be 561.5N, adding the forces from wheel sinkage (169.1N) and furrow opener soil resistance (392.4N).

2.3.1. Determination of the Drive Shaft Diameter

The maximum shear stress of ductile material determines its strength, which is what was meant to be used to construct the shaft. According to (ASME, 1995) the diameter of a shaft with little to no axial force was approximated as follows,

$$d^3 = \frac{16}{\pi Ss} \left[(K_b * M_b)^2 + (K_t * T)^2 \right]^{\frac{1}{2}} \qquad \ldots(5)$$

Where Ss = permissible stress (KN/m^2), Kb = combined shock and fatigue factor applied to bending moment, Kt = combined shock and fatigue factor applied to torsional moment, and Mb = bending moment (N.mm), T = torque (N.mm) and d = shaft diameter (mm) are all given. According to (Khurmi and Gupta, 2005) values of Kb = 1.2 to 2.0 and Kt = 1.0 to 1.50 should be utilized for spinning shafts when a load is supplied abruptly and with minimal shock. Suppose that 120 MN/m^2 is the permissible stress (Ss). As a result, the 30 mm shaft diameter standard size was employed.

Table 3. Parts modified from the existing wheat seed drill

Dimensions of Existing six row seed drill	Dimensions of Modified eight row seed drill
Metering device flute diameter (48mm)	Metering device flute diameter (58mm)
Ground wheel diameter (700mm)	Ground wheel diameter (830mm)
Hopper length (1260mm)	Hopper length (1650mm)
Hopper volume (0.037 m^3)	Hopper volume (0.09 m^3)
Shaft diameter (20mm)	Shaft diameter (30mm)
Overall width (1640mm)	Overall width (2070mm)
No. of Furrow openers (6)	No. of Furrow openers (8)

2.4. Performance Test and Evaluation

The machine was tested to confirm that every functional component could be used, to find and inspect any broken parts, and to look for defects in manufacturing before real tests were carried out in the field or lab.

2.4.1. Laboratory Performance Test

2.4.1.1. Mechanical Damage Test

The percentage seed damage test was performed with the seeder lifted (up) and seeds placed in the hopper. The wheel was revolving ten times. The seed that had emerged from the seed tube was checked for evident damage. The seeds that were visually damaged during the calibration were identified and weighed individually. The percentage damage was calculated using the equation below, as revealed by (Rangapara J., 2014),

$$\%damage = \frac{W_s}{W_{ts}} x100 \qquad \ldots(6)$$

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

2.4.1.2. Seed Distribution Test

The goal of this research was to look into seed metering differences from furrow to furrow. The device's calibration for evaluating seed discharge and damage was done in a lab. There were plenty of wheat seeds in the machine's seed hopper. The measuring flute roller is moved by the driving wheels of the seed drill, which is fixed in a vise. In order to count the number of revolutions while the driving wheel was spun, a paint mark was made on it. To collect the seeds that were released, a seed collecting bag was set up on the discharge tube. Ten low-speed rotations of the driving wheel were performed. After ten revolutions, the seed in each furrow opener bag was weighed, collected, and compared using a balance.

2.4.1.3. Seed Germination Test

The purpose of this test was to determine whether seeds had internal damage. A known quantity of seeds were sowed, and after 10 days after planting, the germinated seeds were counted to determine the percentage of germination, which was then determined as (Rangapara J., 2014),

$$Germination(\%) = \frac{N_{sg}}{N_{sp}} x100 \quad \ldots(7)$$

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

2.4.2. Field Test

Field testing was carried out on adequately prepared and harrowed farmland. Based on the predetermined parameters to be achieved during laboratory investigations, the constructed prototype was operated at the optimal settings selected depending on laboratory evaluation. The seed distribution pattern along rows was analyzed in order to observe seed dispersion along the rows.

Figure 6. Photo taken at 21th days of seedling emergence

During field test, the performance parameters to be measured were time required (hr/ha) which was measured using stop watch, labor requirements, planting costs, plant population, field efficiency, field effective capacity, and seed distribution uniformity were all determined, as well as soil-related parameters such as soil bulk density and moisture content.

2.4.2.1. Moisture Content of Soil

Soil samples were taken from 0 to 10 cm below the soil surface immediately prior operations to measure moisture content and bulk density. Five randomly selected specimens have been selected from the test plots. The samples were placed in a 105°C oven for 24 hours. The samples were weighed before to and after drying. The moisture content (MC) was estimated using Eqn. 19 as published by (Rangapara J., 2014),

$$MC = \frac{M_w - M_d}{M_d} x100 \quad \ldots(8)$$

Where, Mw stands for mass of wet soil sample, Md for mass of dry soil sample, and MC for moisture content.

2.4.2.2. Bulk Density of Soil

The core sampler had been utilized to collect samples in the field. The bulk density of the soil had been determined using the dry weight and volume of the soil sample. The bulk density is computed by dividing the soil's dry weight by its volume. The bulk density of soil was determined using Rangapara J., (2014),

$$BDS(\frac{g}{cm^3}) = \frac{Md}{Vs} \qquad \ldots(9)$$

Where, BDS stands for bulk density of soil (g/cm^3), Md for mass of dry sample (g), and Vs for core sampler volume (cm^3).

2.4.2.3. Operating Speed

The seed drilling machine's operational speed has been determined by measuring the time required to go 20 meters with a timer.

2.4.2.4. Total Operating Time

The total time required for operation for the entire sowing process has been determined by subtracting the time losses for adjustment, turning, and mechanical breakdown from the theoretical time.

2.4.2.5. Theoretical Field Capacity

Theoretical field capacity refers to the rate of coverage of an implement based on 100% of the time at rated speed and 100% of its rated width,

$$TFC(^{ha}/_{hr}) = \frac{Width(m) * Speed(^{Km}/_{hr})}{10} \qquad \ldots(10)$$

2.4.2.6. Effective field capacity

$$\text{Effective field capacity (ha/h)} = \frac{\text{Actual area covered(ha)}}{\text{time required to cover(hr)}} \qquad \ldots(11)$$

2.4.2.7. Field efficiency

$$FE(\%) = \frac{EFC}{TFC} x100 \qquad \ldots(12)$$

2.4.2.8. Fuel Consumption

The fuel consumption has been determined using the standard procedure, which involved observing the fuel required per plot by replacing a known volume of fuel into the fuel tank, and the volume of fuel used was recorded as fuel used. The fuel consumption (liters) was measured and estimated as follows,

$$Fuel\,consumption\,(l/ha) = \frac{Fuel\,consuption(l)}{Area\,covered\,(ha)} \qquad \ldots(13)$$

2.4.2.9. Draft and Power Requirement

Draft has been determined using a dynamometer that was mounted to the tractor supporting the implement. The mounted implement was propelled by another auxiliary tractor after it started working using the dynamometer. The implement-mounted tractor is pulled in neutral gear by the auxiliary tractor, but it stays in the operating position. A distance of 20 meters was used to measure the draft. The tool was raised off the ground and the draft was measured on the same field. The draft of the implement is indicated by the difference between the two readings As expressed by (Rangapara J., 2014),

$$Draft(KN) = Dl - Du \qquad \ldots(14)$$

In the above instance, Dl stands for draft of loaded conditions, and D_U for draft of unloading conditions. The following formula was utilized for estimating the tractor's power consumption,

$$Power(hp) = \frac{Draft(KN)xSpeed({}^{m}\!/_{s})}{75} \qquad \ldots(15)$$

2.4.2.10. Wheel Slip

A skid is a loss of traction from the planter wheels, which can cause it to move uncontrollably. When seed drill machine was operated in soil of prepared seedbed then two flags 20 m apart was erected on the field to mark the test path. The machine allowed to run and counted the wheel revolution to cover 20 m distance without load and in the next run the number of revolution of wheel counted to cover the same distance with load. The drive wheel slip was calculated by using the following Eqn (16) (Rangapara J., 2014),

$$Wheelslip = \frac{A-B}{A}x100 \qquad \ldots(16)$$

The variables A and B represent the number of wheel turns without load and with load, respectively.

2.4.2.11. Plant Population and Uniformity

It was determined by conducting observations at randomly chosen locations for each treatment per square meter area and counting the number of plants within the defined area. The plant homogeneity test was performed by counting the average number of seedlings that emerged per meter distance and calculating the difference between rows.

Figure 7. Photo taken at 10th days of germination count

2.4.2.12. Cost Estimation

With respect to the tractor and machine's capital cost, interest on capital, repair and spare component prices, labor cost, and depreciation, the yearly and hourly operating expenses of the tractor and designed planter were calculated

(Table 4). In Birr (ETB), the operational costs of the prototype planter and the 25-hp tractor have been determined using (Wen-yuan Huang et al., 1979). The seed drill is estimated to require 425 hours year, but the tractor is expected to have an economic life of 10 years and 850 hours annually.

Table 4. Annual and hourly operational costs of the Tractor and fabricated planter

No.	Cost estimation	Formula Used	Sources
	Fixed Cost		
1	Depreciation	$D_P = \frac{PP - SV}{LxH}, (EB/h)$	(Kepener *et al.*, 1987)
2	Interest	$I = \left(\frac{PP+SV}{2}\right) \times \left(\frac{I\%}{H}\right), (EB/h)$	(Kepener *et al.*, 1987)
3	Insurance & taxes (IT)	$IT = 1\% \, of \ PP$	(Kepener *et al.*, 1987)
4	Housing	Housing = 1% of PP	(Kepener *et al.*, 1987)
5	Total fixed cost	$D_p + I + IT + Housing$	(Kepener *et al.*, 1987)
	Variable cost		(Kepener *et al.*, 1987)
6	Repair and maintenance cost	$RM = 10\% \ of \ PP$	(Kepener *et al.*, 1987)
7	Total cost per hour	$Fixed\,cost/hr + Variable\,cost/hr$	(Kepener *et al.*, 1987)

Whereas Salvage value (SV): 10%, interest rate: 10%, Purchase price (Pp): 123,000 ETB Maintenance and repair (RM): 10%, Taxes and insurance (IT): 1% of total pay 1% of PP goes for housing. Fuel consumption: FC = 79.19 ETB per lit, or 4.6 lit/hour. Lubrication consumption: 25% of gasoline, Lubrication cost (LC.): 140 ETB per lit, 300 EB per day is the labor cost (LaC), and Dp is depreciation.

2.5. Experimental Design

Three replications of the randomized completely block design comprised the factorial experimental design. Three levels of hopper loading and three levels of seed drill forward speed, each with three replications, made up the treatments. The experiment consisted of three replications in the experimental design of 3^2, for a total of 27 test runs (3x3x3=27).

2.6. Statistical Analysis

The data was evaluated for variances using GenStat 15th edition statistical software and a process suited to the experimental design (Gomez and Gomez, 1984). The treatment means that differed by 5% had been separated using the least significant difference (LSD 5%) test. The least significant difference (LSD) test was performed to calculate the average seed and fertilizer application rates in relation to forward speed and hopper level of filling.

3. Results and Discussion

3.1. Laboratory Test

3.1.1. Seed drill Calibration Test

The developed wheat seed drill machine was calibrated before actual data collection for obtaining the real seed and fertilizer rate of the seed drill and to see variation of the rates among furrow openers. Table 5 and Table 6 shows that weights of seeds and fertilizers collected from each furrow opener varied from 126.41 to 127.03 kg/ha, and 147.41 to 148.08 kg/ha, respectively. It can be seen that there was no remarkable coefficient of variation of seed and fertilizer rate among the furrow opener for five replications which was ranged from 0.43 to 1.08 % and 0.45 to 1.26%, respectively.

Table 5. Calibrations of Seed rate (kg/ha) for each furrow openers

Weight of seed dropped per seed tube (gm)												
F1	F2	F3	F4	F5	F6	F7	F8	total seed (gm)	mean	sd	CV	seed rate (kg/ha)
65.5	66.4	66.1	65.3	67	64.8	65.6	66.4	527.1	65.89	0.71	1.08	126.41
66.1	66.2	65.8	66.3	65.6	65.3	66.2	66.1	527.6	65.95	0.35	0.53	126.53
65.8	66.5	66.3	66	66.6	66.3	66.4	65.8	529.7	66.21	0.31	0.47	127.03
66.2	66.5	66.1	66.4	66.8	65.7	65.8	66.1	529.6	66.20	0.36	0.55	127.00
65.7	66.3	65.8	66.1	66.4	66.1	66.5	66.3	529.2	66.15	0.28	0.43	126.91
								Average seed rate				**126.77**

Table 6. Calibrations of Fertilizer rate (kg/ha) for each furrow openers

F1	F2	F3	F4	F5	F6	F7	F8	total seed (gm)	mean	sd	CV	Fertilizer rate (kg/ha)
75.6	77.4	78.2	76.5	77.5	77.3	76.8	75.4	614.7	76.84	0.97	1.26	147.41
76.6	77.6	77.4	76.1	77.3	78.2	77.4	76.8	617.4	77.18	0.65	0.84	148.06
77.3	76.7	77.6	76.8	77	77.6	77.4	77.1	617.5	77.19	0.34	0.45	148.08
77.1	76.4	76.9	77.3	77.1	77.6	77.2	75.8	615.4	76.93	0.57	0.74	147.58
78.2	76.7	77.4	76.6	77.2	77.1	77.5	76.5	617.2	77.15	0.56	0.73	148.01
									average			**147.83**

3.1.1.1. Mechanical Damage Test

Table 7 indicates that mechanical damage sustained by the metering mechanism was noticed, but there was no visible damage to the seeds at all of the indicated speeds; this was due to the adjustable flap curvature. Similar results were reported by Pradhan and Ghoshal (2013) and (Abulasan unpublished). Furthermore, a seed germination test was performed before and after seed metering, and 100 seeds were sown in petri dishes. No internal seed damage was observed, implying that the observed 97% germination potential was similar to that predicted by the seed supplier (Ethiopian Seed Enterprise, Asella branch).

Table 7. Data obtained from laboratory test of the seed drill machine

Observations	Speed, km/h	Seed rate obtained, kg/ha	Mechanical damage, %	Germination %
1	3	128.65	0	97

2	4	126.76	0	97
3	5	122.71	0	97

3.1.2. Effects of Seed Drill Operating Speed on Seed Rate

Wheat seed rate was significantly influenced ($p < 0.05$) by the hoper loading level and seed drill forward speed, according to the results of the analysis of variance (ANOVA). Nonetheless, there was no significant difference in the impact of the hoper loading level and seed drill forward speed interaction ($p > 0.05$). The effects of operating speed, hopper loading capacity, and the combined effect of speed and seed filling level in the hopper are presented in Table 8. The relationship between seed drill linear speed and seed rate is depicted in Figure 8.

Table 8. Effects of seed drill operating speed and hopper filling level on seed rate

Parameter	**Source of variation**				**Measure of differences**		**CV (%)**
		Speed level			**LSD (5%)**	**SE(M)**	
		V_3	**V_4**	**V_5**			
Seed rate (Kg/ha)	**Seed rate**	127.22^a	124.12^b	121.4^c	0.16	0.053	
		Hopper filling level					
		H_{50}	**H_{75}**	**H_{100}**			0.1
		124.68^a	124.23^b	123.84^c	0.16	0.053	
		Interaction (V*H)					
	Speed level	**H_{50}**	**H_{75}**	**H_{100}**			
	V_3	127.61^a	127.27^b	126.77^c			
	V_4	124.46^d	124.11^{ef}	123.79^{gh}	0.27	0.091	
	V_5	121.98^i	121.31^{jk}	120.96^{lm}			

Define LSD, SE and CV: Means followed by the same letter (or letters) do not have significant difference at 5% level of probability.

Increasing the speed of operation from 3 to 5 km/hr and the hopper filling level from H_{50} (half) to H_{100} (full) had reduced seed rates. On seed rates, however, the combination of operating speed and hopper filling capacity had no significant effect. With a half-hopper loading capacity and a forward speed of 3 km/h, the highest seed rate of 127.61 kg/ha was attained. Utilizing the maximum hopper capacity and a speed of 5 km/h, the lowest seed rate of 120.96 kg/ha was attained. This revealed unequivocally that reduced seed rates will occur at forward velocities above 5 km/h. Conversely, larger seed rates which above those recommended 125 kg/ha of wheat seeds are produced by forward velocities of less than 3 km/hr (informal communication with experts).

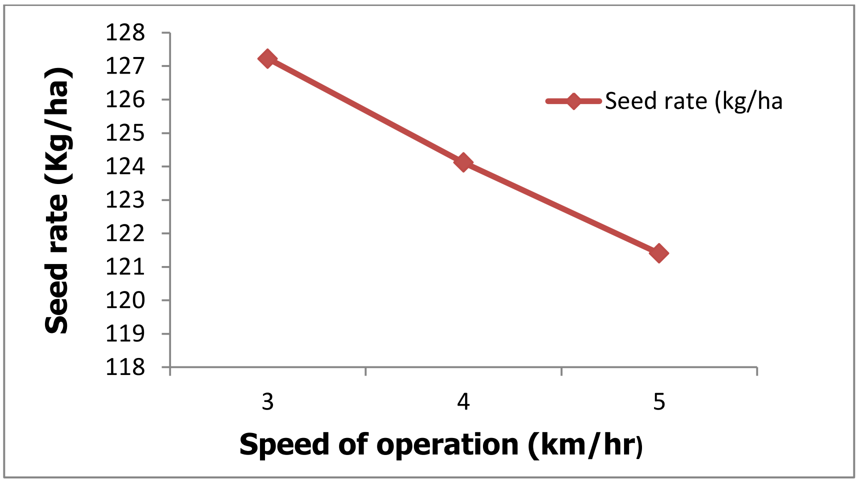

Figure 8. Effects of seed drill linear speed on wheat seed rate

3.1.3. Effects of Seed Drill Operating Speed on Fertilizer Rate

ANOVA revealed that seed drill forward speed and hoper loading level had significant impacts ($p < 0.05$) on fertilizer rate. However, the entire combination of hoper loading level and seed drill forward speed had no significant effect ($p > 0.05$) on fertilizer application rate. Table 9 shows the effects of operation speed, hopper loading capacity, and the combination of speed and hopper filling level on fertilizer rate. Figure 9 indicates the relationship between seed drill linear speed and fertilizer application rate.

Table 9. Effects of seed drill operating speed and hopper filling level on fertilizer application rate

Parameter	**Source of variation**				**Measure of differences**		**CV (%)**
		Speed level			**LSD (5%)**	**SE(M)**	
		V_3	**V_4**	**V_5**			
Fertilizer rate (Kg/ha)	**Fertilizer rate**	152.25^a	148.4^b	146.43^c	0.16	0.055	0.1
		Hopper filling level					
		H_{50}	**H_{75}**	**H_{100}**			
		149.5^a	148.2^b	148.62^c	0.16	0.055	
		Interaction (V*H)					
	Speed level	**H_{50}**	**H_{75}**	**H_{100}**			
	V_3	152.61^a	152.2^b	151.96^b			
	V_4	148.99^c	148.4^{de}	147.84^{fg}	0.28	0.095	
	V_5	146.84^h	146.4^{ij}	146.1^{kl}			

Increasing the operation speed from 3 to 5 km/hr and the hopper filling level from H_{50} (half) to H_{100} (full) reduces fertilizer application rates. However, their combination had no significant effect on application rates. At a forward speed of 3 km/hr and half hopper loading capacity, the highest application rate of 152.61 kg/ha was attained. At a speed of 5 km/h and maximum hopper loading capacity, the lowest application rate of 146.1 kg/ha was attained. This indicated that forward speeds greater than five km/h would yield a lower application rate; conversely, forward speeds below 3 km/h would yield a higher application rate, beyond the recommended 150 kg/ha of NPS fertilizer rate (informal communication with experts).

Overall, Table 9 indicates that the amount of fertilizer particles in the hopper and forward speed significantly impacted the application rate, but the operational speed and hopper filling level alone had no appreciable impact. However, it is evident that the effect was mainly brought about by differences in filling rates and hoper levels, not by their combination.

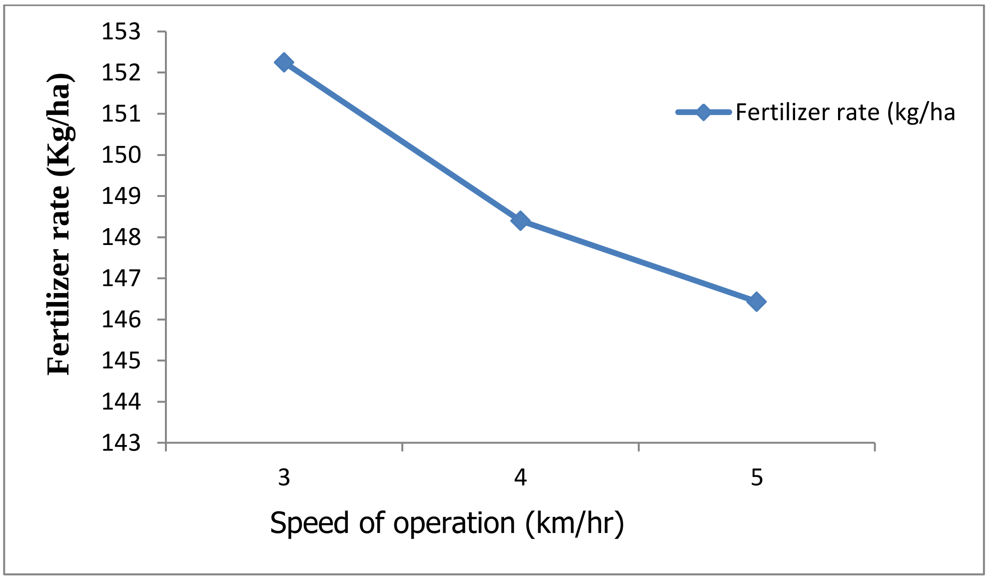

Figure 9. Effects of seed drill linear speed on fertilizer application rate

3.2. Field Test

The seed drill was tested on farmers' farmland for its mechanical and functional performances in a field area of 20 x 50 m^2 in the Hetosa district. Among wheat varieties, DKA wheat variety was sown for the study. Wheat was sown in the field with 20-cm row spacing.

3.2.1. Moisture Content of the Soil

The average moisture content at 20 cm depth, measured on a dry basis, has been found to be 19.39% for five randomly selected soil samples that were taken at various locations in the field.

3.2.2. Bulk Density of Soil Sample

The bulk density of the soil sample was determined using a core sampler and the oven-dry method. The sample was weighed first, and then baked in an oven at 105 °C for 24 hours. After drying, the sample weight was measured again, and the average bulk density for the experimental field was determined to be 1.42 g/cm^3.

3.2.3. Theoretical and Effective Field Capacity of the Seed Drill

The seed drill's average theoretical field capacity at 3, 4, and 5 km/hr was 0.48, 0.64, and 0.8 ha/hr, respectively. It was found that the effective field capacity was 0.44, 0.57, and 0.70 ha/hr at different speeds of 3, 4, and 5 km/hr (Table 10). Figure 10 shows that increasing the speed of the seed drill increased both theoretical and effective field capacity. According to this data, a hectare of land can be planted by a seed drill in around 1.43 to 2.27 working hours, depending on operation speed.

Table 10. Field performance results on (20 x 50 m^2) plot

Operating Speed, km/h	Fuel Consumption, l/hr	TFC, ha/hr	EFC, ha/hr	FE,%	Wheel Slip,%	Net draft requirement (N)
3.00	2.5	0.48	0.44	90.92	1.67	255.8
4.00	3.6	0.64	0.57	89.41	3.09	284.8
5.00	4.6	0.80	0.70	87.11	4.67	301

3.2.4. Field Efficiency

Table 10 presents the average field efficiency values that were achieved. At a speed of 5 km/h, the minimum field efficiency was 85.71%, while at a speed of 3 km/h; the highest field efficiency was 92.31%. As speed increases, field efficiency declines, as seen in Figure 10. The principal reason for the decrease in field efficiency when forward speed was increased was the shorter theoretical duration compared to the other test plots (Rangapara J., 2014).

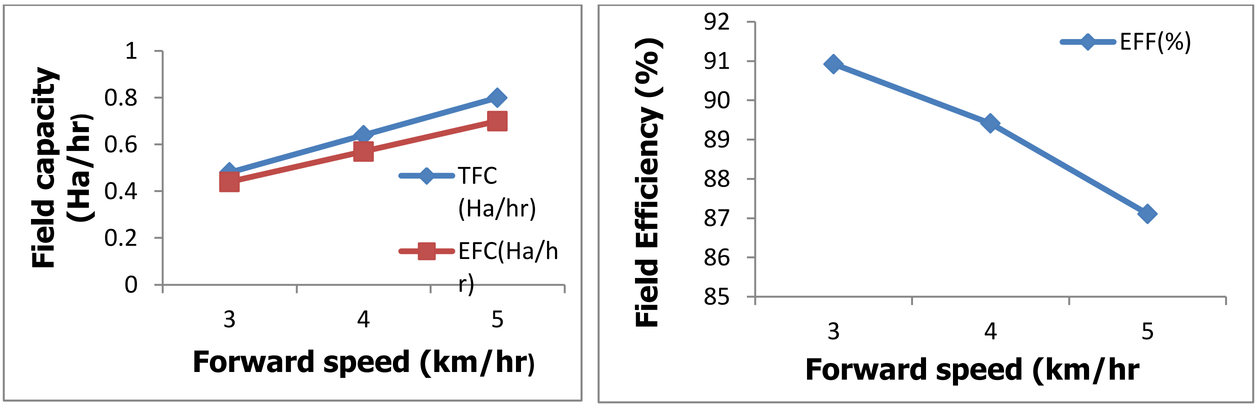

Figure 10. Effects of seed drill linear speed on-field capacity and field efficiency

3.2.5. Draft Requirement and Wheel Slip

Utilizing a spring dynamometer, the draft required to run the modified seed drill was determined. For 3, 4, and 5 km/hr, the average draft values were 255.8, 284.8, and 301 N, respectively (Table 11). The minimum wheels slip 1.54 % and maximum wheel slip 5.81 % was observed at speed of 3 km/h and 5 km/h, respectively. Figure 11 shows that both draft and wheel slippage when operating the developed seed drill tend to rise with increasing operating speed.

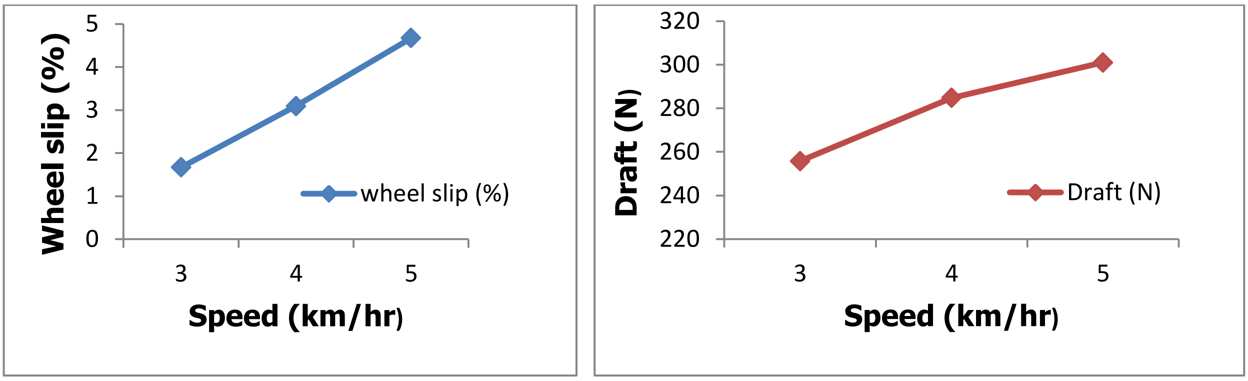

Figure 11. Effects of seed drill linear speed on draft requirement and wheel slip

3.2.6. Economical Evaluation

The tractor-drawn seed drill machines required simply one operator to drive them. The time required to plant and fertilizer a hectare of land using a six-row tractor-drawn seed drill with one operator was 3 hours per hectare at a speed of 5 km/hr (Abulasan Keberedin, 2023), whereas a single person using the tractor-drawn seed drill machine required only 1.42 hours per hectare at a speed of 5 km/hr to accomplish the same task. As a result, using eight-row tractor-drawn seed drills at 5 km/hr reduces the time required per hectare by more than two times that of a row planter.

3.3. Conclusions and Recommendations

3.3.1. Conclusion

The mechanical seed damage test findings showed that there was no visible damage to the seeds at all of the specified speeds, which was due to the adjustable flap curvature that avoided friction and impact between the seeds and the fluted roller. From germination test results, it can be concluded that there was no internal damage to the seed at different speeds.

The rates of wheat seed and fertilizer were significantly affected ($p < 0.05$) by the seed drill forward speed and hoper loading, while the rates of wheat seed and fertilizer were not significantly effected ($p > 0.05$) by the interaction between the two factors. The rates of seed and application had dropped when the operation was accelerated from 3 to 5 km/h and the hopper filling was increased from H_{50} (half) to H_{100} (full). Nevertheless, there was no discernible difference in rates between the operational speed and hopper filling capacity combination.

This shown conclusively that higher forward speeds than 5 km/h produced a lower seed rate, while slower forward speeds than 3 km/h produced a higher seed rate, beyond the recommendations of 125 and 150 kg/ha of fertilizer and wheat seeds, respectively. However, as can be seen, rather than their combination, the effect was mostly brought about by differences in filling rates and hoper levels.

The average theoretical field capacity of the seed drill was 0.48, 0.64, and 0.80 ha/hr at 3, 4, and 5 km/hr. Effective field capacity on well-prepared areas was 0.44, 0.57, and 0.70 ha/hr at comparable speeds of 3, 4, and 5 km/hr, respectively. This suggests that both the theoretical and actual field capacities of the seed drill enhanced the in tandem with its speed. According to this research, a hectare of land can be seeded by a seed drill in 1.42 to 2.27

working hours, depending on how quickly it operates. Consequently, utilizing a tractor-drawn seed drill at a speed of 5 km/h reduces the time needed per hectare by three times as compared to utilizing an animal-drawn planter, too.

3.3.2. Recommendations

The results of the performance studies showed that farmers may effectively use the seed drill machine for sowing activities. Despite this, there is a problem that needs to be addressed before farmers can find seed drills more useful, popular, and adaptable.

- Seed drill machine should be used on well prepared land being at friable stage or at moisture ranges between 13 and 17 %.
- From this research finding, it can be recommended that 4 km/hr operating speed and half hopper filling level is the point where seed drill performs better in terms of optimum seed and fertilizer rate of application.

Declarations

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Competing Interests Statement

The authors have declared that no competing financial, professional or personal interests exist.

Consent for publication

All the authors contributed to the manuscript and consented to the publication of this research work.

Availability of Data and Material

Supplementary information is available from the authors upon reasonable request.

Authors' contributions

All the authors took part in literature review, analysis, and manuscript writing equally.

References

Abulasan Kabaradin (2023). On-Farm Evaluation of Tractor Drawn Wheat Seed Drill. International Journal of Precision Farming, 1(1): 16–24. https://doi.org/10.54536/ijpf.v1i1.2175.

ASAE (1994). Three-Point Free-Link Attachment for Hitching Implements to Agricultural Wheel Tractors. ASAE S217.12 DEC2001 (ISO 730-1:1994) (R2007) Power, 01.

ASME (1995). Design of transmission shafting. American Society of Mechanical Engineering.

Ashebir Tsegaye & Abayineh Awigichew (2023). Redesigning of Asella Animal Drawn Wheat Row Planter. Applied Research and Innovation, 1(2): 24–31. https://doi.org/10.54536/ari.v1i2.2053.

CSA (Central Statistical Agency) (2021). The Federal Democratic Republic of Ethiopia Central Statistical Agency Report on Farm Management Practices. Statistical Bulletin, III, 512.

Hussain, M.I., Shah, S.H., Hussain, S., & Iqbal, K. (2002). Growth, Yield and Quality Response of Three Wheat (*Triticum aestivum* L.) Varieties to Different Levels of N, P and K. Int. J. Agri. Biol., 4(3): 362–364.

Kepener (1987). Principals of Farm Machinery (8th Ed.). TCBS.

Khurmi, R.S., & Gupta, J. (2005). A Textbook of Machine Design. In text book. Eurasia Publishing House.

Kurtz, G., Thompson, L., & Clwar, P. (1984). Design of agricultural machinery. John Willey and Sons, Singapore.

MK, P., et al. (2013). Performance study of a low cost manually Operated cup feed metering seed drill for sowing green gram Bhubaneswar. International Journal of Agricultural Engineering, 5(1): 6–11.

Kalay, K., & Moses, S.C. (2017). Performance Evaluation of Manually Operated Multi- Crop Planter for Okra. Journal of Pharmacognosy and Phytochemistry.

Olaoye, J.O., & Bolufawi, S.J. (2001). Design, fabrication and performance of multi-purpose row planting machine. Sustain. Environ., 3(1): 7–20.

Rangapara, J. (2014). Development of mini tractor operated picking type pneumatic planter. Anand Agricultural University. http://krishikosh.egranth.ac.in/handle/1/96661.

Reece (2002). The Mechanics of Tractor Implement Performance. In Transactions of the American Society of Agricultural Engineers, R.H. Macmillan.

RNAM (1991). Agricultural Machinery Design and Data Handbook (Seeders and Planters). Economic and Social for Asia and Pacific.

Wen-yuan, H., et al. (1979). Calculating Costs of Using Farm Machinery. Hawaii Agricultural Experiment Hawaii Agricultural Experiment Station, College of Tropical Agriculture and Human Resources, University of Hawaii.