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

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ABSTRACT

The purpose of this study was to design, develop, and assess the performance of a prototype seed drill that could simultaneously create ridges and furrows, sow wheat seeds, and apply fertilizer at predefined row spacing. A frame, seed and fertilizer hoppers, a seed and fertilizer metering device, a furrow and ridge former, and a power transmission system make up the developed seed drill machine. Seed and fertilizer rate, row spacing, depth of seed placement, plant count/stand, field capacity, field efficiency, labor cost, and economics of ownership and operation were all taken into consideration when evaluating the performances. Three operating speeds, three flap position levels, three hopper fill levels, and three replications were all included in the fully randomized experimental design. When compared to the germination percentage of the seed recommended by the seed supplier, the investigation test results showed that there was no decrease in the percentage of visible and invisible mechanically damaged seed for any variety. According to wheat agronomic requirements, the seed and fertilizer rates were calibrated at 161.53 kg/ha and 156.70 kg/ha, respectively, for 20 cm row spacing and 5 cm depth. Three flap positions lower, mid, upper, and hopper filling levels of H25, H50, and H75 were used to assess the seed drill. While hopper filling capacity of the seed drill had no significant effect on seed and fertilizer rate at $p > 0.05$, flap position had a significant effect at $p < 0.05$. At 6 km/h, the average field capacity, field efficiency, and fuel consumption were 0.61 ha/hr, 84.72%, and 9.76 l/hr, respectively. During the field germination count, 386 plants were found per square meter. The results of the performance evaluation indicate that most farmers can use the developed raised bed seed drill at the upper flap position and half hopper filling level in an efficient and cost-effective manner.

INTRODUCTION

In addition to being the world's most significant cereal crop, wheat is also a crucial strategic food crop for Ethiopians. According to UNDP (2013), wheat is typically planted as a winter crop by either manually spreading the seed, on a level soil surface and then incorporating it through shallow tillage after planting and flood irrigation, particularly in irrigated areas, or by drilling the seed in rows while maintaining a row-to-row distance of 20 cm.

One of the few nations in Africa with comparatively plentiful water resources, a pleasant climate, and potentially vast irrigable land is Ethiopia. Ethiopia is estimated to have 3.7 million hectares of potentially irrigable land with surface water resources, and 386,603 hectares of land are estimated to be irrigated through the development of both traditional and modern irrigation schemes (MoWR, 2005). Ethiopia plans to use irrigation to produce wheat during the off-season in order to grow the wheat sector to the necessary level (Anteneh & Asrat, 2020).

One effective irrigation technique is furrow-irrigated raised bed technology, which involves planting crops on raised beds while water flows through a furrow. Water distribution was enhanced by bed and furrow planting systems, which also decreased the amount of water needed for irrigation, increased water use efficiency in the wheat cropping system, and provided drainage in fields that were flooded. For improved crop stand establishment and yield, the seed and basal fertilizer dose are uniformly metered in lines on a well-prepared seed bed using a seed-cum fertilizer drill. Raised bed planting increases nitrogen use efficiency, decreases crop lodging, allows band fertilizer application, and offers a chance for mechanical weed control.

In recent years, raised-bed crop planting has become increasingly popular in other nations. This technology makes up 2 to 18 percent of irrigated areas in Mexico, Syria, Pakistan, Indonesia, the US, Canada, and other countries, greatly increasing yields. While the farmer's practice involves preparing the land, spreading the seed, and shallow cultivation with the cultivator, the raised-bed planter involves sowing in line and creating ridges and furrows with the ridger. By adapting this cutting-edge planting technology to Ethiopia's soil and climate, winter wheat yields will raise and farmer welfare will be enhanced.

The lack of row planting technology posed a significant obstacle to the government's and farmers' efforts to implement irrigation-based wheat production methods. The size of the field that can be sown in irrigation-based wheat production is limited by the laborious manual method of row planting, which leads to poor seed placement, low spacing efficiencies, and severe back pain for the farmer due to the longer hours needed for careful hand metering of seeds.

There are no planting technologies that are used for furrow irrigation-based wheat and lessen the workload of

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farmers, despite the government's high need to produce wheat crops through irrigation. In order to develop and assess the performance of a tractor-drawn raised bed driller for irrigation wheat cultivation, this project was started.

MATERIALS AND METHODS

Descriptions of Study Area

The Assella Agricultural Engineering Research Center, which is situated in the Arsi zone of the Oromia Region and has a latitude of 6° 59' to 8° 49' N, a longitude of 38° 41' to 40° 44' E, and an elevation of 2,430 meters above sea level, was the site of the design, fabrication, testing, and evaluation.

Design Considerations

A wheat seed drill pulled by a tractor was created as a practical and experimental device. The primary operation and functional requirement served as the foundation for the drill component design.

Agronomic Requirement of Wheat

According to Agronomists and researchers, the agronomical requirements of irrigation wheat seed and fertilizer drill was 160 kg and 150 kg per hectare respectively and the row spacing were 20 cm.

Descriptions of the Machine

The major components of ridge and furrow making seed-cum-fertilizer drill machine (Fig. 1) are main frame, hopper, ground wheel power transmission system, metering device (fluted roller type), and furrow openers, ridger, seed and fertilizer delivery spout and tubes and hitching system. The various parts of the planter were designed for the structural strength for the selected materials and the dimensions were obtained. Below are the specifics of the prototype's various parts.

Figure 1: The photo of developed raised bed irrigated wheat row planter

Determination of Working Width of Seed Drill

The working width of the machine were determined from desired area of land to be covered, speed of operation, estimated field efficiency, and available working day(s)/ hour(s). Furthermore, the weight of the drill and soil resistance against the furrow openers was estimated to decide up on the size of the drill.

According to Sharma and Mukesh (2010), the speed of sowing operation is from 4 to 6 km/hr. and assume that eight working hours, field efficiency of 80% and furrow spacing is 20cm.

$$Desired\,hectares = \frac{W(m)xS(\frac{km}{hr})x\eta\,x(workinghours)}{10} \quad 1$$

W stands for width (m), S for speed of operation (km/h), = field efficiency percentage, and Sp for furrow spacing (m).

Hence, the width of the machine was determined by considering desired land to be covered is 340 ha, total working hours is 350hr and speed of operation is 6 km/ hr.

$$Width(m) = \frac{340(ha)x10}{6(\frac{Km}{hr})x0.8x350} = 2m \quad 2$$

Therefore, wheat seed drill with six furrow openers and four ridger was developed.

Frame

The machine's skeletal structures serve as its main frame, supporting all other parts. Consequently, a mild steel square section (60 mm × 60 mm × 6 mm) was used to fabricate the machine's main frame (200 cm x 65 cm). The setup for fixing the hopper, power transmission mechanism, three-point linkage, seed placement furrow openers, and ridger was given.

Hopper Design

The hopper has two compartments along its length one for seeds and the other for fertilizer and is shaped like a trapezoid at the bottom and rectangular at the top. It also has a lid with an easy-to-open handle. It was constructed from 1.5 mm thick iron sheet. The average bulk density of wheat seeds (833.06 kg/m^3) and the angle of repose (300) were taken into account when designing the seed hopper. As a result, the hopper is divided into two compartments along its length one for seeds and the other for fertilizer and has a trapezoidal shape at the bottom and a rectangular shape at the top. The following formula was used to calculate the hopper's volume (Olaoye and Bolufawi, 2001).

$V= S_R/(n \times BD)$ 3

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

$$V = \frac{160(Kg/ha)}{2 \times 833.06(Kg/m^3)} = 0.096\,m^3$$

The following box's assumed dimensions were used to calculate the seed hopper's actual volume. Top width (b) = 28 cm; bottom width (a) = 20 cm; height (hR) = 10 cm , Length = l = 200 cm; Height (hT) = 10 cm, VR is the volume of the hoper's rectangular portion, and VT is the volume of its trapezoidal portion.

The following formula was used to determine the box's volume using the assumed dimensions mentioned above (Sharma and Mukesh, 2010).

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

$$V = V_R + V_T = 200*28*10 + \frac{1}{2}(2*20 + 2*200)*10*28 \quad 4$$

$$V = 117{,}600\,cm^3 = 1.17\,m^3$$

As a result, the hopper was designed with two equal-sized compartments: one for seeds and another for fertilizers, each measuring 0.58 m^3.

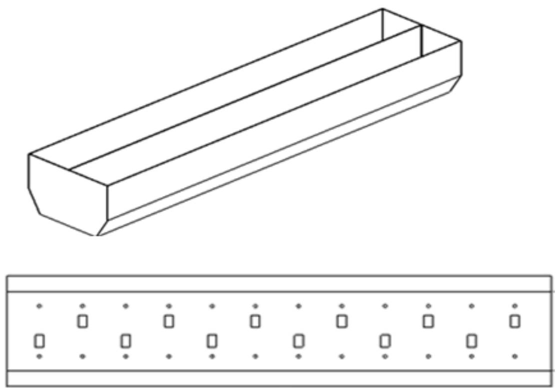

Figure 2: Isometric view of hopper

Fertilizer and Seed Metering Device

The fluted roller metering device was made of circular aluminum alloy of fluted roller was designed along the length of a roller having 10 mm diameter and 5 mm depth for each flute and 5 mm spacing between the flutes according to (RNAM, 1991), which suggests that the roller's flute count should be between eight and twelve. The seeds in the seed hopper gradually fill each flute as the ground wheel rotates. Based on the physical characteristics of wheat seeds, a fluted roller dimension was chosen. The diameter of the fluted roller, which was calculated using the following formula based on the desired number of flutes and their spacing, is crucial in the measured amount of seeds dropped per unit area.

$$V_S = \frac{160 \times 0.2}{10x0.833} = 3.84cm^3$$

Where Vs is the volume of seed dropped per meter of row length; s is the seed rate in kilograms per hectare; > is the bulk density of seed in grams per centimeter; and r is the row spacing in meters.

The following formula was used to determine the cross-sectional area of a semi-circular flute (Murray *et al.,* 2006).

$$A_f = \frac{\pi d^2{}_f}{8}$$

$$A_f = \frac{\pi x(1)^2}{8} = 0.39cm^2 \quad 5$$

Where df = diameter of a flute, cm

The exposed length of the fluted roller was calculated by the following formula.

$$l_f = \frac{8 \times s \times r \times d_g}{10 \times \rho \times d_f^2 \times N_f \times i} \quad 6$$

The transmission ratio were a unit, as rotation of ground wheel facilitate seed metering device mounted on ground wheel shaft to rotate. Therefore,

$$L_f = \frac{8 \times 160 \times 0.2 \times 0.34}{10 \times 0.833 \times (1)^2 \times 10 \times 1}$$

$$L_f = 1.05\ cm \quad or\ 10.5\,mm$$

Where, L_f = exposed flute length, cm; s = wheat seed rate, kg/ha; □ = bulk density of seed, g/cm^3; r = row spacing, m; df = flute diameter, cm; Nf = number of flutes; dg = ground wheel diameter, m; and i = transmission ratio.

The volume of seeds delivered per revolution of fluted rollers was determined by the equation below.

$V_d = A_f\ N_f\ L_f$

V_d = 0.39 x 10 x 1.05 7

V_d = 4.10 cm^3

Where: A_f = area of semi-circular flute, N_f = number of flutes, L_f = exposed length of fluted roller, cm

$d_f = (N_f\ (d_f - s_f))/\ \pi$ 8

Where df is the flute's diameter (mm), sf is the distance (mm) between flutes, dr = fluted roller diameter (mm), Vs is the volume of seed dropped per meter of row length; s is the seed rate in kilograms per hectare; > is the bulk density of seed in grams per centimeter; and r is the row spacing in meters.

The fluted roller's diameter was therefore determined to be 58 mm.

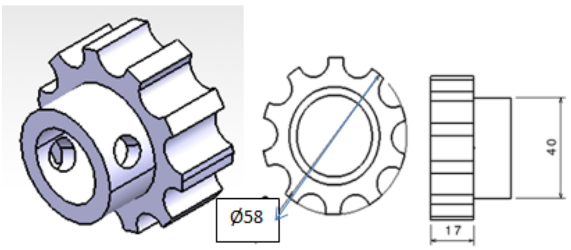

Figure 3: Isometric view of seed metering fluted roller

Hitching System

To connect the planter to the tractor, a three-point hitch assembly is installed in the front position of the main frame. Flat iron with a thickness of 16 mm was used to create a three-point hitching system. ASAE (2007) was used to determine the geometry dimensions for mast height, lower hitch point span, and mast and hitch pin hole distance. The system's measurements are as follows: lower hitch point spread of 650 mm, height of 600 mm, and hitch pin diameter of 25 mm. The machine was attached to a hydraulically controlled tractor using a three-point linkage located at the rear end of the tractor.

Ridger

The ridger s hitched to the planter frame to make uniform furrow and ridges before drilling of wheat seeds and fertilizer at one pass of the machine. The ridger was provided with adjustable curved wings of mould board shape. The wings were hinged to the shank. The shank was fabricated from 76 mm × 25 mm and having a height of 650 mm mild steel flat bar to which wings were hinged.

Furrow Opener

Bolts and nuts are used to secure six furrow openers to the planter's front side frame. The openers can be moved vertically to change the depth. The seeds and fertilizers enter the furrow opener through seed and fertilizer delivery tubes and are released into the soil through boots as the furrow openers open the soil.

Covering Devices

The soil lifted and thrown by the furrow opener's wings at the back will cover the dropped seeds and fertilizer, negating the need for a separate seed and fertilizer covering device.

Ground Wheel

The seed and fertilizer metering mechanism was powered by a lugged ground wheel. Eight lugs and 90 mm mild steel flat with a thickness of 3 mm were used to create a 340 mm diameter spike lugged ground wheel. In order to drive the seed and fertilizer metering mechanism without slippage, lugs measuring 95 mm in length were welded equally apart on the periphery of the ground wheel. In order to minimize wheel slip and the absence of a seed metering mechanism, a spring was installed between the main frame and the wheel arm to keep the wheel pressed against the ground during the sowing process.

Power Transmission System

For seed metering, power was transferred from the ground wheel via sprockets and a chain. An intermediate shaft installed above the main frame receives power from the ground wheel via a chain and sprocket. The main frame provides the necessary support arms for the intermediate drive shaft. Through a chain and sprocket, the drive is transferred from the intermediate shaft to the seed and fertilizer metering shaft. The bottom grooves of the seed and fertilizer hopper support the metering flute shaft.

Performance Test and Evaluation

Two sets of tests were conducted: field tests to determine the machine's actual overall performance, and laboratory research to calibrate the prototype in terms of seed rate and seed damage.

Laboratory Testing

Mechanical Seed Damage Test

With the seed driller held (raised up) and the seeds loaded into the hopper, the test for percentage seed damage was conducted. Twenty turns of the wheel were made. We looked for any external damage to the seeds that were released from the seed tube. After identifying and gathering all of the seeds that were clearly damaged during the calibration, each damaged seed was weighed individually, and the percentage of damage was computed as (Rangapara J., 2014).

$$\text{Seed damage } (\%) = (W_s/W_{ts}) \times 100 \quad (9)$$

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

Seed Distribution Test

The purpose of the test was to study how the seed metering devices varied from furrow to furrow. The ground wheel of the seed drilling machine was turned 20 times at a predefined flap position and hopper loading in order to evaluate the uniformity of the seeds. To collect the seeds released during the test run, seed collecting bags were positioned beneath each seed tube. There were three replications of each test run. Following each test run, the seeds gathered in the bags for each furrow opener were weighed on a balance and compared.

Seed Germination Test

The purpose of the test was to determine whether or not the seed drill machine caused internal seed damage. In order to determine the germination percentage, 100 wheat seeds obtained from a seed drilling machine were sown on a petri dish. Ten days later, the germinated seeds were counted, and the germination percentage was computed as (Rangapara J., 2014). Next, the computed germination percentage was compared to what Ethiopian Seed Enterprise had determined.

$$\text{Germination } (\%) = (N_{sg} / N_{sp}) \times 100 \quad (10)$$

Where, N_{sg}= the number of seeds sown; N_{sp}= the number of seeds that sprouted

Field Performance Testing

The field tests were conducted at Tiyo districts of Katar genet irrigation scheme. The test plot was prepared by tractor to obtain a fine seedbed for irrigation wheat row planting. The John Deere tractor 5065E (75 hp) was used for field test. Seed rate, seed uniformity, and seed damage were noted based on the ideal parameters found in laboratory research. Soil parameters, including soil bulk density and moisture content, effective field capacity, field efficiency, and uniformity of seed distribution, were identified during the field test.

Moisture Content of Soil
Prior to operations, soil samples were taken at a depth of 30 cm from the soil's surface in order to measure bulk density and moisture content. From the test plots, five samples were chosen at random. The samples were weighed both before and after drying, and they were kept in an oven at 105°C for a full day. Rangapara J. (2014) calculated the moisture content (Db).

$MC= ((M_w-M_d)/ M_d) \times 100$ 11

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

Bulk Density of Soil
A field sample was taken using the core sampler. The dry weight of the sample and the soil sampler's volume were used to calculate the bulk density of the soil. The soil's bulk density was determined using (Rangapara J., 2014).

$BDS\ (g/cm^3)= Md/Vs$ 12

Where, Md is the mass of the dry sample (g), Vs is the volume of the core sampler (cm3), and BDS is the bulk density of the soil.

Operating Speed
Using a stopwatch, the time needed to travel 40 meters was measured in order to determine the seed drilling machine's operating speed.

Theoretical Field Capacity
The tractor's travel speed and operating width were taken into account when calculating the theoretical field capacity. The formula was used to measure the theoretical field capacity, which was expressed in ha/h.

$$TFC(ha/hr) = \frac{Width(m) * Speed(Km/hr)}{10} \quad 13$$

Effective Field Capacity
Time losses for each event during field testing, i.e. turning losses and seed and fertilizer replenishment in the planter were noted. However, the time spent on productive work and the time lost on other tasks like turning and replenishing fertilizer and seed were noted when determining the effective field capacity (ha/hr).

$$Effective\ field\ capacity(ha/hr) = \frac{Actual\ area\ covered\ (ha)}{Time\ required\ to\ cover\ (hr)} \quad 14$$

Field Efficiency
Field efficiency (Ef) was calculated using the formula below and expressed as a percentage.

$$FE(\%) = \frac{EFC}{TFC} x100 \quad 15$$

Ridge to Ridge Spacing
A steel scale was used to measure the ridge-to-ridge spacing (in centimeters) during the field trial. Five randomly selected locations in the field were used to measure the ridge-to-ridge spacing.

Row to Row Spacing
While conducting the field trials of the irrigation wheat row planter the spacing between two adjacent rows (cm) was measured with the help of steel tape. The row to row spacing was measured in the field at five different locations randomly.

Plant Population and Uniformity
It was calculated by counting the number of plants within the area and making observations at randomly chosen locations for each treatment per square meter. The average number of seedlings that emerged in each row per meter was counted as part of the plant uniformity test, and the variation between the rows was calculated.

Experimental Design and Statistical Analysis
The data from laboratory experiments was analyzed using the Completely Randomized Design (CRD) to determine the interactions between the combinations factor. Three levels of hopper loading and three levels of seed drill forward speed were employed as treatments, each with three replications. The analysis of variance and mean comparison were performed using R statistical software. At the 5% significance level, the critical difference was discovered.

RESULTS AND DISCUSSIONS
The results of the investigation have been discussed and explained in this chapter. In order to fully accomplish the project's goals, this chapter discusses the outcomes of experiments. The tractor-drawn ridge and furrow irrigation wheat row planter experiments were carried out both in the field and in the lab. Seed rate, effective field capacity, and field efficiency were taken into consideration when evaluating this machine's performance in the field of a model farmer in the Tiyo districts of the Katar genet irrigation scheme. The following subsections provide a report and discussion of the study's findings.

Laboratory Performance Test
Raised Bed Seed Drill Calibration Test
Prior to data collection, the developed tractor-drawn raised bed wheat seed drill machine was calibrated to determine the actual seed and fertilizer rate of the seed drill and to observe variations in rates among furrow openers. In order to test and modify the planter to achieve the intended plant population, the driller was calibrated. In twenty drive wheel revolutions; there were 414 g of wheat seed and 413.72 g of fertilizer. Tables 1 and 2 show how the fertilizer and wheat seed rates differ between rows (furrow openers). It was noted that all of the samples were almost identical. Tables 1 and 2 present specific calibration observations. The information showed that the weights of the fertilizer and seeds taken from each furrow opener ranged from 155.36 to 157.26 kg/ha and 157.1 to 161.7 kg/ha, respectively. These demonstrate that the rates of wheat seeds and fertilizer that were observed were almost identical to those that experts and researchers recommended, which were 160 kg/ha and 150 kg/ha, respectively.

Table 1: Seed rate obtained from developed seed drill

No. of observation	Weight of seed from each furrow opener per 20 revolution, gm						Total seed collected (gm)	Mean	SD	Seed rate (kg/ha)
	$F.O._1$	$F.O._2$	$F.O._3$	$F.O._4$	$F.O._5$	$F.O._6$				
1	68.3	69.7	70.2	68.8	68.5	69.1	414.6	69.10	0.73	161.76
2	69.6	68.8	69.3	69.4	68.2	69.1	414.4	69.07	0.50	161.69
3	69.2	68.8	68.7	69.2	68.5	69.4	413.8	68.97	0.35	161.45
4	69.3	68.4	69.4	69.1	69.1	68.4	413.7	68.95	0.44	161.41
5	68.5	69.5	68.5	69.6	68.9	68.5	413.5	68.92	0.52	161.33
Average seed rate (kg/ha)										**161.53**

Note: - F.O means Furrow Opener

Table 2: Fertilizer application rate obtained from developed machine

No. of observation	Weight of fertilizer from each furrow opener per 20 revolution, gm						Total fertilizer collected (gm)	Mean	SD	Fertilizer rate (kgha)
	$F.O._1$	$F.O._2$	$F.O._3$	$F.O._4$	$F.O._5$	$F.O._6$				
1	69.8	67.2	68.6	69.7	67.1	69.1	411.50	68.58	1.19	155.86
2	68.7	68.6	69.4	67.2	69.8	70.5	414.20	69.03	1.14	156.88
3	69.1	67.8	70.4	68.8	70.8	67.2	414.10	69.02	1.41	156.84
4	70.8	68.7	69.1	68.5	68.2	68.3	413.60	68.93	0.97	156.66
5	69.1	69.8	68.6	69.4	69.1	69.2	415.20	69.20	0.39	157.26
Average fertilizer rate (kg/ha)										**156.70**

Seed and Fertilizer Distribution Test

The differences in seed and fertilizer distribution between the rows (furrow openers) are displayed in Tables 1 and 2. It was found that all of the samples taken for the same hopper filling and flap position were almost identical, with only minor variations between the rows (0.35–0.73 for seed and 0.39–1.41 for fertilizer). The variation in seed rate from the six row metering was less because there had been less variation. This result indicates that the percentage variation was within the permissible range of ± 5% (Tomar, 1983). Senger *et al.* (2011) also reported similar outcomes when using animal-drawn rice cum green manure crop seeder to sow wheat in dry soil.

Effects of Flap Position and Hoper Filling on Seed Rate

The flap position had a significant impact ($p < 0.05$) on wheat seed rate, according to the analysis of variance (ANOVA) table, whereas the hoper filling level and the interaction of hoper filling level and forward speed had no significant impact ($p > 0.05$). The effects of flap position, hopper filling capacity, and the combination of flap position and hopper seed filling level on wheat seed rate are displayed in Table 3. The correlation between seed rate and linear flap position is depicted in Figure 4. The impact of flap position on seed rate is depicted in Fig. 4. This was because the rotating flute roller prevents

Table 3: Effect of Flap position and hopper filling level on seed rate

	Source of variation			Measure of differences
Flap Position	F_{up}	F_{mid}	F_{lwr}	LSD (5%)
	161.09[a]	159.43[b]	158.77[b]	0.699
Hoper filling level	H_{25}	H_{50}	H_{75}	0.699
	160.33[a]	159.76[ab]	159.2[b]	
	Interaction(V*H)			
Flap Position	H_{25}	H_{50}	H_{75}	1.21
F_{up}	161.29[a]	161.18[a]	160.81[a]	
F_{mid}	160.16[ab]	159.29[bc]	158.85[cd]	
F_{lwr}	159.54[bc]	158.82[cd]	157.95[d]	

At the five percent probability level, means that are followed by the same letter (or letters) do not differ significantly the seed from being placed in its flute when the flap is lowered.

Effects of Flap Position and Hopper Filling Level on Fertilizer Application Rate

The flap position had a significant impact on fertilizer application rate ($p < 0.05$), according to the analysis of variance (ANOVA) table, whereas the hoper filling level and the combined effect of hoper filling level and flap position had no significant impact ($p > 0.05$). The effects of flap position, hopper filling level, and the combination of flap position and fertilizer filling level on the fertilizer application rate are displayed in Table 4. The impact of flap position on fertilizer application rate is depicted in Fig. 5. For all hopper filling levels, the rate of fertilizer application drops as the flap position shifts from upper to lower.

Table 4: Effect of flap position and hopper filling level on fertilizer application rate

	Source of variation			**Measure of differences**
Flap Position	F_{up}	F_{mid}	F_{lwr}	LSD (5%)
	157.24a	156.26b	155.64b	0.672
Hoper filling level	H25	H50	H75	0.672
	156.53ab	155.93b	156.68a	
	Interaction(V*H)			
Flap Position	H_{25}	H_{50}	H_{75}	1.164
F_{up}	157.13ab	156.65bc	157.93a	
F_{mid}	156.33bcd	155.8cd	156.65bc	
F_{lwr}	156.12bcd	155.33d	155.47d	

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

Mechanical Seed Damage Test

Because the flap curvature was adjustable to prevent friction and impact between the seeds and the fluted roller, there was no visible damage to the seeds at any of the chosen flap positions, according to Table 5's visual observations for mechanical damage caused by the metering mechanism. Pradhan and Ghoshal (2012) reported similar results. Moreover, the seed germination test, which involved sowing 100 seeds in trays before and after metering, revealed no internal seed damage. The observed germination potential of 99% was consistent with the prediction provided by the seed supplier (Ethiopian Seed Enterprise, Asalla branch).

Table 5: The data gathered from the seed drill machine's laboratory test

Observations	**Flap position**	**Seed rate obtained, kg/ha**	**Mechanical damage, %**	**Germination %**
1	Upper	161.09	0.0	98
2	Middle	159.43	0.0	99
3	Lower	158.77	0.0	99

Field Performance Test

In the Tiyo district of the Kater Genet irrigation scheme, a 50 x 50 m2 field area was used to test the seed drill's mechanical and functional capabilities. The King Bird wheat variety was selected for the study out of all the wheat varieties. Wheat was sown in the field with a 20 cm row-to-row spacing and a 60 cm ridge-to-ridge distance.

Moisture Content and Bulk Density of Soil

At a random from various locations within the field, five soil samples were taken at a depth of 20 cm from the soil's surface. Table 6 shows the average data on soil density and moisture content prior to tillage operations at depths of 0 to 20 cm. The average soil moisture content and bulk density of the soil mass in the experimental plot were determined to be 15.56% and 1.44 g/cc, respectively. Therefore, when testing the raised bed irrigation wheat row planter, these soil factors were taken into account.

Table 6: Bulk density and soil moisture content under field conditions (dry basis)

Replication	**Mass of wet soil (Mw), gm.**	**Mass of dry soil (Md), gm.**	**Soil moisture content, %**	**Volume of core sampler, Cc**	**Bulk density, g/cc**
1	642.6	554.4	15.91	384.85	1.44
2	641.3	550.5	16.49	384.85	1.43
3	639.2	556.7	14.82	384.85	1.45
4	631.3	551.4	14.49	384.85	1.43

5	646.7	557.2	16.06	384.85	1.45
Mean	**640.22**	**554.04**	**15.56**	**384.85**	**1.44**

Theoretical, Effective Field Capacity and Field Efficiency of Seed Drill

At operating speeds of 6, 7, and 8 km/h, the raised bed seed drill's mean theoretical and effective field capacities were found to be 0.72, 0.84, and 0.96 ha/h and 0.61, 0.68, and 0.74 ha/h, respectively (table 7). Figure 6 illustrates how the raised bed wheat seed drill's theoretical and effective field capacity increased as speed increased. At operating speeds of 6, 7, and 8 km/h, respectively, the field efficiency was found to be 84.72%, 80.95%, and 77.08%. At an operating speed of 8 km/h, the lowest field efficiency was 77.08%, while at a speed of 6 km/h, the highest field efficiency was 84.72%. Figure 6 shows that as speed increased, field efficiency decreased. Rangapara J. (2014) proposed that when the field size was reduced, the number of drill passes also increased, which resulted in higher time losses and lower field efficiency values. Compared to the other test plots, less theoretical time was used, which the main cause of the decrease in field efficiency was caused by increasing forward speed. This indicates that, depending on the speed of operation, a hectare of land can be sown by a seed drill in roughly 1.35 to 1.64 working hours.

Table 7: Average of Measured Seed Drill Performance Evaluation during Field Test

Sr. No.	Parameters	Values		
1	Working width, m	1.2	1.2	1.2
2	Operating speed, km/hr	6	7	8
3	Theoretical field capacity, ha/hr	0.72	0.84	0.96
4	Effective field capacity, ha/hr	0.61	0.68	0.74
5	Field efficiency, %	84.72	80.95	77.08

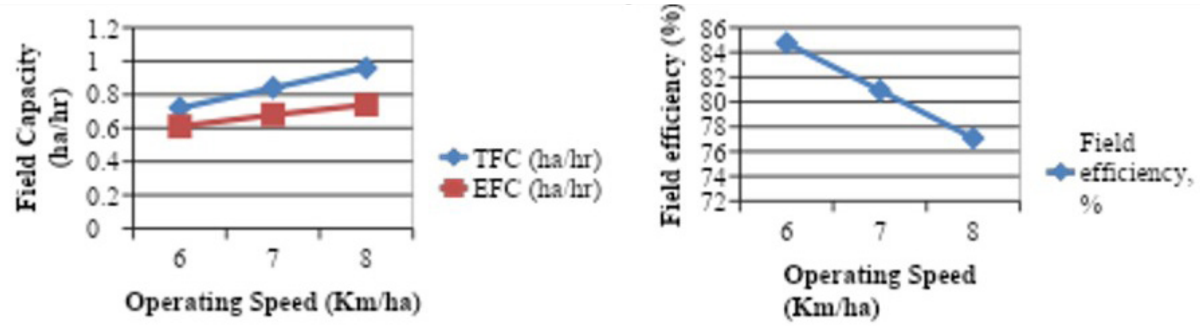

Figure 4: Forward speed's effects on field efficiency, effective field capacity, and theory

Figure 5: Raised bed wheat seed drilling and wheat after 28 days of planting

When compared to flat-sown wheat, bed-planted wheat (Figs. 5) performed better in terms of seed, fertilizer, growth, active tillers, and irrigation water savings. In the early stages of the crop, mechanical weeding in furrows was simple.

Height and Width of Ridge

Table 8 displays the height and width measurements of the ridges created by the planter. The ridge's height ranged from 19.7 to 22 cm, with an average of 20.72 cm. The average ridge width was 31.57 cm and varied from 30.2 to 34 cm at the bottom, indicating that the ridges are uniform.

Table 8: Ridge's Height and Width

S/No.	Height of Ridge (cm)	Bottom width of Ridge (cm)	Top width of Ridge (cm)
1	22	34.0	15
2	20.8	30.5	13.8
3	20.4	31.5	14.2
4	19.7	32.8	14.5
5	20	30.2	14.8
6	21.4	30.4	14.7
Avg.	**20.72**	**31.57**	**14.50**

Plant Population and Uniformity

In accordance with the methodology, the germination count was conducted in the field. Following the sowing of a king bird wheat variety with a germination potential of 98.7% (Ethiopian seed enterprise, Asalla branch), 386 plants were counted as the mean number of seeds that germinated per 1 m2 area after fifteen days. 392 plants were intended to be planted in a 1 m2 area. Therefore, the requirement for the establishment of the ideal plant population for wheat seeds was reasonably satisfied by the seed drill. Nonetheless, there were some differences between the recommended and actual seed emergence at the field; these differences could be caused by environmental factors.

Summary, Conclusions and Recommendations

Summary

The data showed that the weights of the fertilizer and seeds taken from each furrow opener ranged from 155.36 to 157.26 kg/ha and 157.1 to 161.7 kg/ha, respectively. These demonstrate that the observed rates of seeds and fertilizer were almost identical to those suggested by experts and researchers, which were 160 kg/ha and 150 kg/ha for wheat seeds and fertilizer, respectively. The distribution test for seed and fertilizer reveals that all of the samples taken for the same flap position and hopper filling were almost identical, with very little variation between the rows (0.35 to 0.73 for seed and 0.39 to 1.41 for fertilizer). The variation in seed rate from the six-row metering was less because there had been less variation. This finding indicates that the percentage variation was within the permitted range of ± 5% (Tomar, 1983). Senger *et al.* (2011) reported similar outcomes when using animal-drawn rice cum green manure crop seeder to sow wheat in dry soil.

Three flap positions lower, mid, upper, and hopper filling levels of H25, H50, and H75 were used to assess the developed raised bed seed drill machine. While hopper filling capacity of the seed drill had no significant effect on seed and fertilizer rate at $p > 0.05$, flap position had a significant effect at $p < 0.05$. At operating speeds of 6, 7, and 8 km/h, the raised bed seed drill's mean theoretical and effective field capacities were found to be 0.72, 0.84, and 0.96 ha/h and 0.61, 0.68, and 0.74 ha/h, respectively. This demonstrates that as speed increased the raised bed seed drill's theoretical and effective field capacities both increased. This generally showed that, depending on the speed of operations, a hectare of land could be sown by a seed drill in 1.35 to 2 working hours. Additionally, the highest field efficiency recorded at a speed of 3 km/h was 84.72%, while the lowest field efficiency was 77.08% at an operating speed of 8 km/h. It is evident that as speed increased, field efficiency decreased. Rangapara J. (2014) proposed that when the field size was reduced, the drill's number of passes increased as well, increasing time losses and producing lower field efficiency values. Compared to the other test plots, less theoretical time was used, which the main cause of the decrease in field efficiency was caused by increasing forward speed.

After 15 days of sowing, a germination count revealed an average of 386 plants per square meter. 392 plants were intended to be planted in a 1 m2 area. Therefore, the requirement for the establishment of the ideal plant population for wheat seeds was reasonably satisfied by the seed drill.

CONCLUSION

It is clear from the above summary that the developed raised bed seed drill machine performs satisfactorily in terms of seed and fertilizer rate, depth of seed and fertilizer placement, attaining the ideal plant population, field capacity, field efficiency, labor cost, and economics of owning and operating the machine. Therefore, it can be said that most Ethiopian farmers can use the developed raised bed seed drill effectively, economically, and efficiently. To avoid significantly and adversely affecting the recommended plant population or the rate of seed and fertilizer, the machine's speed should not surpass 8 km/h.

According to the performance evaluations, farms can effectively use the raised bed seed drill machine. However, in order to increase the raised bed seed drill's usability, popularity, and adaptability among farmers, the following issue needs to be resolved.

- ➢ For smooth metering, the fertilizers must be free of clods and the seed must be clean and graded. Use only granular fertilizers that measure easily and consistently, if at all possible.
- ➢ The raised bed wheat seed drill may undergo rigorous testing, and comprehensive trials on various soil types are required to validate the findings.
- ➢ Take into consideration the depth control wheels.

To prevent an excessive draft load on the tractor, the machine's depth of operation should be restricted to the depth of the tilled soil.

- In general, the results are promising and demonstration at large scales are recommended to all irrigation wheat producing areas of the region.

REFERENCES

Anteneh, A., & Asrat, D. (2020). Wheat production and marketing in Ethiopia: Review study. *Cogent Food and Agriculture, 6*(1). https://doi.org/10.1080/23311932.2020.1778893

Ministry of Water Resources (MoWR). (2005). *Ethiopian water resources management policy.*

Murray, J. R., Tullberg, J. N., & Basnet, B. B. (2006). Planters and their components. In *Planters and their components* (pp. 142–154). http://www.grdc.com.au/growers/gc/gc58/notill.htm

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

Rangapara, D. J. (2014). *Development of mini tractor operated picking type pneumatic planter* (Unpublished thesis). Agricultural University, Godhra.

Regional Network for Agricultural Machinery (RNAM). (1991). *Agricultural machinery design and data handbook (seeders and planters).* Economic and Social Commission for Asia and the Pacific.

Sharma, D. N., & Mukesh, S. (2010). *Farm machinery design: Principles and problems* (2nd ed.). Jain Brothers.

Singh, S., & Vasta, D. (2007). Development and evaluation of a lightweight power tiller-operated seed drill for hilly regions. *Journal of Agricultural Mechanization in Asia, Africa and Latin America.*

Theodore, B. (1985). *Mechanical engineering handbook* (pp. 6–16). McGraw-Hill.

United Nations Development Programme (UNDP). (2013). Raised-bed planting in Egypt: An affordable technology to rationalize water use and enhance water productivity. *Science Impacts,* 4.