

Research Article

Modification and Performance Evaluation of AAERC Tractor Drawn Wheat Row Planter to PTO Driven Wheat and Fertilizer Drilling

Merga Workesa^{*} , Matiwos Belina, Solomon Lemmessa

Oromia Agricultural Research Institute, Bako Agricultural Engineering Research Center, West Shewa, Ethiopia

Abstract

Wheat constitutes staple food for more than 35% of world population. Regionally, the highest amounts of wheat are produced in Oromia and followed by Amhara. Planting is a process of placing seeds in the soil to have good germination. This method is notably slow, laborious, time-consuming, and costly, often leading to inadequate seed placement and spacing, increased labor demands, and consequently, lower yields and productivity. The former-developed and customized wheat and fertilizer planting machines have several issues, including the design of the hopper, the method of metering, and the fact that they are tractor-drawn, which results in uneven distribution of seeds and fertilizers due to the use of a land wheel for metering. Hence the project concentrated on improving and assessing the efficiency of the PTO-driven wheat and fertilizer drilling machine, including the demonstration of how to apply engineering methods to minimize the need for manual labor and which made furrow for irrigated wheat. Testing and performance evaluation were made to quantify the effects of PTO speed, tractor forward speeds and hopper loading level on theoretical field capacity, effective field capacity, row spacing, seed distribution uniformity and grain yield. The observations recorded from different plots indicate that the average theoretical field capacity, effective field capacity, and field efficiency of the drilling machine were 0.67 ha/hr, 0.55 ha/hr, and 81.78% at the first forward speed level; 0.84 ha/hr, 0.63 ha/hr, and 75.51% at the second forward speed level; and 1 ha/hr, 0.75 ha/hr, and 74.7% at the third forward speed level, respectively.

Keywords

Drilling, Field Capacity, Forward Speed, Parameters

1. Introduction

Wheat is among the most important staple food crops and a major diet that is consumed by more than 2.5 billion people globally [2]. It is a staple food in all parts of the world and supplies 35 % of food and provides 20 % of the calories [4]. Wheat is cultivated on an estimated 217 million ha, making it the most widely grown crop in the world, and in terms of

production it accounts for 752 M tonnes [5]. Wheat (*Triticum aestivum*L.) constitutes staple food for more than 35% of world population. The Ethiopian Statistics Services [1] report that wheat makes up approximately 12.2% of the land used for cultivation (1.9 million hectares), 20.2% of the total output, and provides jobs for 4.9 million small-scale farmers

^{*}Corresponding author: mergaw180@gmail.com (Merga Workesa)

Received: 2 September 2025; **Accepted:** 13 September 2025; **Published:** 10 October 2025



Copyright: © The Author(s), 2025. Published by Science Publishing Group. This is an **Open Access** article, distributed under the terms of the Creative Commons Attribution 4.0 License (<http://creativecommons.org/licenses/by/4.0/>), which permits unrestricted use, distribution and reproduction in any medium, provided the original work is properly cited.

who rely on it for their livelihoods. Regionally, the highest amounts of wheat are produced in Oromia (about 53% of the land used and 57-58% of the total output), followed by Amhara (34% of the land used and 28-32% of the output), SNNP (8% of the land used and 8% of the output), and Tigray (5% of the land used and 3-6% of the output) [1]. The role of irrigation in increasing production level is clear from the perspective of production ecology, where it removes soil moisture limitation from production levels and raises the yield ceiling to potential yield level [6, 8, 10].

Planting is a process of placing seeds in the soil to have good germination. It is one of the most important cultural practices associated with crop production. An exercise which should result in plant stands at the desired density that emerges quickly and uniformly [11]. A good seed planting gives the correct amount of seed per unit area, correct depth at which seed is placed in the soil and correct spacing between row-to-row and plant-to-plant [12]. Uniform seed distribution within the soil results in better germination and emergence increased yield by minimizing competition between plants for available resources such as light, water, and nutrients. A number of factors affected the seed distribution in soil such as the seed metering system, seed delivery tube, furrow opener design, physical attributes of seed, and soil conditions [3].

The process of seed sowing is inherently labor-intensive, particularly when conducted traditionally. Therefore, the mechanization of this process is essential for enhancing operational efficiency and increasing yield. In any agricultural endeavor, the timeliness of operations is a critical factor that can only be achieved through the use of suitable machinery [7].

In Ethiopia, particularly in the Oromia region, seed planting is predominantly performed by hand. This method is notably slow, laborious, time-consuming, and costly, often leading to inadequate seed placement and spacing, increased labor demands, and consequently, lower yields and productivity. The seed planters, which can be either power-driven or manually operated, are agricultural machines designed for sowing seeds in the field. An effective planter should ensure that seeds are placed in conditions conducive to reliable and viable germination. The primary advantages of using such equipment include the reduction of time wastage, the assurance of even spacing and uniformity, the enhancement of agricultural output, and the alleviation of the laborious nature of crop cultivation, making farming more appealing. Various types of planting machinery, including precision planters, grain drills, broadcasters, and vegetable planters, are available in the market, each offering different precision levels and distribution patterns based on their design and metering mechanisms [1].

Precision planters contribute to seed conservation, minimize labor hours, and achieve more consistent spacing and planting depth, which are crucial for producing crops that are uniform in height and strength, essential for maximizing yield. To mitigate the dependence on human labor for sow-

ing which often leads to delays, reduced output, and elevated production costs, there is a pressing need to develop and adopt indigenous planting equipment. Significant advancements have been made in planter development by researchers for various crops. Despite the growing interest in the mechanization of the seeding process, there remains a necessity to further innovate in seed planting technologies.

El-Din Mohamed Nasr et.al. [14] conducted an assessment of the effectiveness of walking tractor-drawn wheat drills. The findings indicated that an operating speed of 2.5 km/h was optimal for sowing, achieving the desired seed rate, uniformity, and spacing. The theoretical field capacity was determined to be 0.3 ha/h, while the actual field capacity was recorded at 0.25 ha/h, both measured at an average speed of 2.5 km/h for the shovel-type furrow opener. Additionally, the average field efficiency was calculated to be 77.9 percent. Another report by [13] presents the performance evaluation of a walking tractor, determining that the theoretical field capacity, effective field capacity, and field efficiency of the machine are 0.30 ha/hr., 0.23 ha/hr., and 77.91%, respectively. Conversely, AAERC has developed and constructed a tractor-drawn wheat row planter and has carried out field performance evaluation to gather empirical data regarding its overall effectiveness in comparison to the imported tractor-mounted wheat row planter. As reported by [18], the theoretical field capacity for both types of row planters was established at 0.42 ha/hr. In contrast, the actual field capacities and efficiencies for the two planters were recorded at 0.37 ha/hr and 0.36 ha/hr, with field efficiencies of 88.10% for the imported planter and 85.71% for the adapted version.

The AAERC has developed and customized wheat and fertilizer planting machines, but these machines have several issues, including the design of the hopper, the method of metering, and the fact that they are tractor-drawn, which results in uneven distribution of seeds and fertilizers due to the use of a land wheel for metering.

Therefore, the project aimed on improving and assessing the efficiency of the AAERC tractor-mounted wheat seed drill for PTO-driven operations, including the demonstration of how to apply engineering methods to minimize the need for manual labor and which made furrow for irrigated wheat.

2. Materials and Methods

Experimental Site

The manufacturing of the seed drill machine was done at Bako Agricultural Engineering Research Center (BAERC), which is located in West Shewa. It lies between 9°04' 45" to 9°07' 15" N latitudes and 37°02' to 37°07' E longitude in sub-humid agro-ecological zone. The mean minimum and maximum air temperatures are 13.20 and 27.90, respectively. The performance evaluation of the seed and fertilizer drilling machine was conducted at west Shewa zone of Ambo and Ejersa Lafo Districts.

Descriptions of Seed and fertilizer Drilling machine

The seed and fertilizer drilling machine was designed for both irrigated and rain-fed wheat seeding, by providing an attachment for ridge formation to facilitate water management. The machine consists of hopper with two chambers for seed and fertilizer, designed in a parabolic shape to ensure the complete discharge of both during the sowing process.

Eight numbers of fluted rollers each for seed fertilizer metering were installed and two parallel arranged power transmission shafts, chain and sprockets, gear box, knife type furrow opener, supporting frame, seed and fertilizer delivery tube, ridger for furrow making for simple water managements were provided.

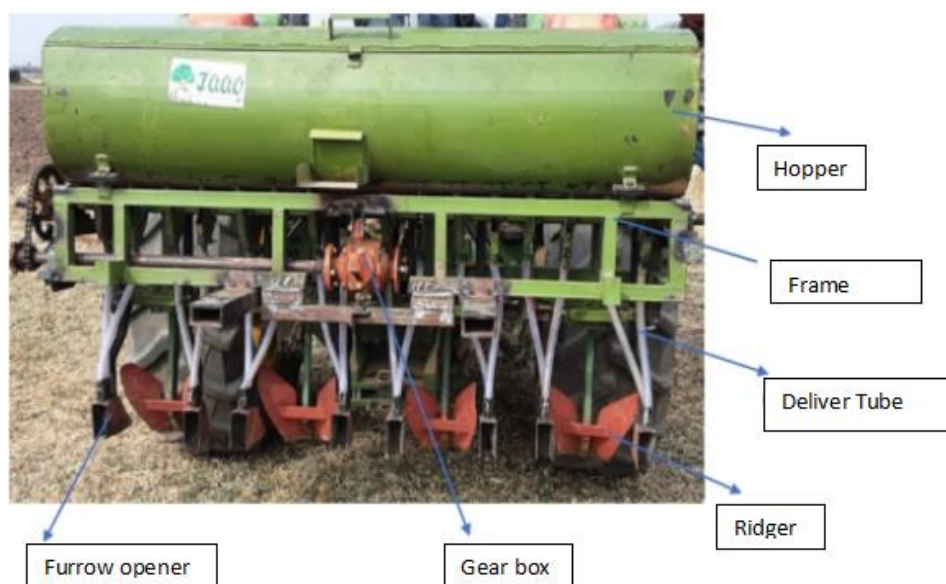


Figure 1. Major component parts of the drilling machine.

Considerations and Material Selection

When developing the prototype, it is crucial to consider multiple factors. This involves assessing the mechanisms from the previous prototype, selecting appropriate materials, simplifying the design, and addressing aspects such as weight, durability, ease of manufacturing and maintenance, while also striving to reduce production costs for the target end users. Achieving these objectives requires a comprehensive approach that combines the physical and engineering properties of the crops with the necessary functional requirements. Important factors to consider include configurations for seedlings, the physical characteristics of seeds, the availability of fundamental engineering designs, the strength of construction materials, safety and ergonomics of the machine, ease of operation, power needs, maintainability, reliability, and the efficiency of the machine's components.

Materials

The materials used for construction of the prototype were angle iron, mild steel shaft, sheet metal, iron rods, gear box, bearing, bolts and nuts, hose, fluted rollers, chain and sprockets.

Modified parts

Hopper

The hopper was manufactured from 1.5 mm thick mild steel sheet metal, the hopper measures 1660 mm in length, 430 mm in width, and 320 mm in height, and is divided into

two equal compartments for the storage of seeds and fertilizers. Assuming the blanket recommendation of seed rate for wheat seed to be 150 kg/ha and two times refill the hopper volume was calculated to be 0.096 m³ for seed and fertilizer by using Eqn (1) below; since the bulk density of seed and fertilizer is 833.06 kg/m³ and 944.66 kg/m³, the hopper has the capacity of 80.03 kg and 90.69 kg respectively.

$$V = \frac{Sr}{n \times BD} \quad (1)$$

Where: - S_R = seeding rate (kg/ha), n = number of refilling per hectare, BD = bulk density of the seeds (kg/m³)

Frame

In selecting the material for the frame, two critical design considerations were weight and strength. Given that the frame will bear the attachments of the furrow openers, ridgers, hitch, seeds and fertilizer hopper, PTO shaft it will experience torsional and bending stresses due to the induced draft. Consequently, mild steel square hollow section measuring 40 mm x 40 mm with a thickness of 4 mm was utilized to ensure the necessary strength and rectangular pipe of 50 mm by 30 mm by 3 mm was used to enforce the stress concentration section due to draft force from ridger and furrow opener.

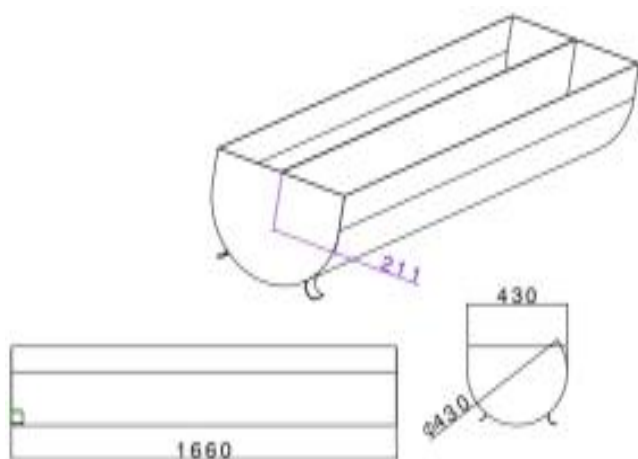


Figure 2. Seed and fertilizer hopper.

Hitching

The hitching system was constructed using U-shaped iron measuring 80 mm by 80 mm by 8 mm, along with flat iron measuring 80 mm by 8 mm. It features a slot that allows for the adjustment of the distance between the implement and the tractors, thereby accommodating drilling machines for various tractor sizes.

Metering devices

The seed metering device featuring fluted rollers was constructed from circular aluminum alloy. The design incorporated slots (flutes) extending along the length of a roller with a diameter of 12 mm and a depth of 5 mm for each flute, maintaining a spacing of 5 mm between the flutes. This design adheres to stipulates that the number of flutes on the roller should range from 8 to 12. Furthermore, as reported by [1], the dimensions of the fluted rollers were determined based on the physical characteristics of wheat seeds, establishing the roller's length and diameter at 19.9 mm and 58 mm, respectively.

Furrow openers

The main frame of the planter was equipped with eight furrow openers, secured by a bolt and nut system that allows for vertical adjustment to modify the depth of operation. The selection of the shoe type furrow opener was made intentionally, incorporating a delivery tube that is designed to be plugged from the rear.

Ridger

The dimensions of the ridger were determined based on the agronomist's recommendations for irrigated wheat cultivation, with a width of 30 cm to ensure adequate water channels between the rows. The drilling machine was equipped with four ridgers, capable of forming furrows for eight rows in a single pass.

Prototype manufacturing and development

The initial adaptation of the wheat and fertilizer drilling machine was completed, leading to the fabrication of a prototype. Following preliminary testing, it was determined that the metering mechanism required modification to utilize PTO

power transmission. This drilling machine serves a dual purpose for irrigated wheat planting, as it is fitted with both a furrow opener and a ridger. During conventional wheat planting, the ridgers are removed, allowing only the furrow openers to be employed. After a thorough review of the previous machine's design, the prototype was successfully fabricated according to the specified dimensions for each component.

Test and Performance Evaluation of Seed Drill Laboratory Test

This performance test include the calibration of the seeder as well as a seed germination test. It aimed to ascertain the seed dropping rate achievable at various settings and to examine the differences among furrow openers while the seed drill remained stationary.

Seed Damage Test

The seed samples obtained after passing through the metering system was examined to identify any visible damage. The calculation of the percentage of damaged seeds was performed in accordance with the methodology outlined by using the equation provided below Eqn (2) [15].

$$SD = \frac{\text{Weight of damaged seed(kg)}}{\text{Total weight of seed collected(kg)}} \times 100 \quad (2)$$

Seed Uniformity observation

This experiment was carried out at the center to determine uniformity of the seed without engaging the furrow opener to soil to observe the seed following through the delivery tube, and finally the bags were attached to each rows to determine the seed and fertilizer rate. A 50-meter track was established on a clear surface, and the appropriate PTO speed was selected. The tractor was then operated at various speeds to evaluate the distribution of seeds and fertilizers. To minimize seed scattering, the seed delivery tube was positioned as close to the ground as feasible. Activities were conducted over different duration along the length corresponding to the recommended seed rate, and observations were recorded. These procedures was repeated a minimum of three times, and an average of the seed and fertilizer rate were calculated.

Seed Emergence Test

This test was conducted to find visible damage to seed by metering mechanism. The seeds before and after metering were taken out for germination. Take the Petri dish and it covers with blotting paper and adds some amount of water for wetness. The germinated seed was counted and percentage of seed germination was found out. The seed emergence was calculated using equation (3) below.

$$SE = \frac{\text{number of seed germinated}}{\text{number of seeds planted}} \times 100 \quad (3)$$

Field Test

Various measurements were taken, including total area covered, operating duration, effective width, furrow width, and furrow depth. Throughout the testing process, observations were recorded regarding the ease of operation and adjustment,

as well as any maintenance or safety features present.

Planter Performance Evaluation

Performance evaluation was conducted to investigate measurable parameters, including the quantity of seeds dropped per row, the percentage of seed damage, effective field capacity, plant population uniformity, field capacity, and operational efficiency. The drilling machine was evaluated for both irrigated and rain-fed wheat planting on a well-prepared experimental site located in the West Shewa Zone, specifically in the Ambo and Ejersa Lafo Districts.

Soil physical property determination

The alteration of soil physical properties due to climate change can initiate a series of effects that significantly impact the growth and yield of crops, such as wheat. Important indicators of soil physical properties in the context of climate change encompass soil structure, water infiltration rate, bulk density, rooting depth, and soil moisture content.

Moisture content of soil

Soil samples were obtained from the top 0 to 10 cm of the soil surface prior to operations to assess moisture content and bulk density. A total of five samples were randomly selected from the test plots. These samples were then placed in an oven for 24 hours at a temperature of 105 °C. Weights were recorded before and after the drying process. The moisture content (Db) was calculated using the equation (4) provided below [17].

$$MC = \frac{M_w - M_d}{M_d} \times 100 \quad (4)$$

Where, MC= moisture content, Mw= mass of wet soil sample, and Md = mass of dry soil sample

Bulk density of soil

The core sampler was used to take sample from field. The bulk density of the soil was determined from dry weight of the sample and volume of the soil sample. The ratio of dry weight of soil to the volume gives the bulk density. Bulk density of soil was calculated by using Eqn (5) [1].

$$BDS(g/cm^3) = \frac{M_d}{V_s} \quad (5)$$

Where, BDS= bulk density of soil (unit); Md=mass of dry sample (g); Vs=volume of core sampler (cm³)

Performance parameter determination

The performance evaluation involved the assessment of various performance parameters, including theoretical field capacity, effective field capacity, field efficiency, and operating speed. Furthermore, measurements were taken regarding the time required to complete the test plot, total productive time, non-productive time, effective width, furrow depth, and furrow width.

Theoretical Field Capacity (ha/hr)

The field coverage rate of the implement was calculated based on the assumption of operating at 100 percent of its rated speed while covering the full width of its specifications. This rate was established using Equation (6) as outlined be-

low.

$$TFC = \frac{\text{Theoretical width(m)} \times \text{speed(km/hr)}}{10} \quad (6)$$

Effective Field Capacity (EFC)

The effective field capacity was determined by measuring the area cultivated within a specified time frame. This observation was repeated three times for each treatment and the field capacity was then calculated using Equation (7).

$$EFC = \frac{\text{Area covered(ha)}}{\text{time taken to cover the test area(hr)}} \quad (7)$$

Field Efficiency

The field efficiency is the ratio of the effective field capacity to the theoretical field capacity, usually measured in terms of percentage and it was determined by using the following Eqn. (8).

$$FE = \frac{EFC}{TFC} \times 100 \quad (8)$$

Germinated Seed distribution uniformity determination

The measurement was conducted using squares measuring 50 cm by 50 cm, with counts taken from each randomly selected plot for each treatment applied to the plants within the designated area. The uniformity of plant distribution was assessed in relation to each treatment combination, focusing on the number of seedlings that emerged in each row per meter and the variations observed among the rows.

Experimental design

The experimental design employed a factorial combination with a split-split plot Design, incorporating two levels of PTO speeds (540 and 1000 rpm), three levels of tractor forward speeds (4, 5 and 6 km/hr), two levels of hopper loading (half and full) for irrigated wheat planting. In total, the experimental design comprised 36 test runs, calculated as 2×3×2, resulting in 36.

Data management and presentation

The data underwent a variance analysis in accordance with the experimental design methodology outlined by [9], utilizing GenStat 18th edition statistical software. The treatment means were distinguished through the least significant difference (LSD) at 5% confidence level. This LSD test was conducted to compare the mean values of the actual seed and fertilizer application rates concerning forward speed and hopper fill level.

3. Results and Discussion

The physical characteristics of the seeds examined in this study were analyzed to refine the design of the planter's components. Performance metrics such as field capacity, field efficiency, and seed distribution uniformity were employed to evaluate the planter's effectiveness. This section presents the calibration of seeds and fertilizers, soil property determination,

the assessment of mechanical seed damage, and the findings from the performance evaluation of the machine.

Soil physical property

Soil samples were taken randomly from the test site at different depth to determine soil types, textural class, and

moisture content and soil bulk density. As illustrated in the [Table 1](#) the average bulk density of 1.2 g/cm³ and soil moisture content of 42.29% in wet base were determined. The soil types were categorized texturally under [Table 1](#).

Table 1. Soil physical property determination.

Soil Depth (cm)	Sand	Silt	Clay	Textural Class	Mean BD g/cm ³	Mean %MC
0-30	14	24	62	Clay	1.20	42.29
30-60	10	26	64	Clay		
60-90	8	22	70	Clay		

Seed rate calibration test

[Tables 2 and 3](#) present the weights of seeds and fertilizers collected from each fluted roller at the end of the delivery tube. It is evident from these tables that there was a consistent variation observed among the outlets of the delivery

tubes. The standard recommendation for the seed rate of irrigated wheat is approximately 150 kg/ha; therefore, the seed rate was adjusted in accordance with this guideline, resulting in a final rate of 138 kg/ha for seeds and 150 kg/ha for fertilizers [\[16\]](#).

Table 2. Seed rate calibration determination.

Replication	Weight of seed delivered through tube (gm)								Seed rate (kg/ha)
	R1	R2	R3	R4	R5	R6	R7	R8	
1	120	118	123	123	118	119	126	124	124.75
2	126	122	122	127	127	126	120	128	123.13
3	122	125	115	125	120	128	125	125	124.00
4	124	120	121	127	126	124	123	127	121.13
5	120	118	119	126	122	122	118	124	125.88
6	127	121	124	124	129	127	129	126	123.50
7	124	125	116	123	126	125	125	124	122.50
8	122	123	121	120	120	126	122	126	123.28
average	123.13	121.50	120.13	124.38	123.50	124.63	123.50	125.50	121.38
SD	2.59	2.78	3.23	2.39	4.00	2.92	3.51	1.51	
CV	0.02	0.02	0.03	0.02	0.03	0.02	0.03	0.01	

Table 3. Fertilizer calibration.

Replication	Weight of fertilizer delivered through tube (gm)								Fertilizer rate (kg/ha)
	R1	R2	R3	R4	R5	R6	R7	R8	
1	119	120	147	152	150	134	136	129	123.28

Replication	Weight of fertilizer delivered through tube (gm)								Fertilizer rate (kg/ha)
	R1	R2	R3	R4	R5	R6	R7	R8	
2	120	122	148	158	151	139	134	131	135.88
3	121	128	152	158	154	141	134	133	137.88
4	122	127	143	153	152	133	134	132	140.13
5	121	125	145	155	149	134	132	131	137.00
6	118	129	146	152	153	140	133	132	136.50
7	122	124	144	151	149	138	135	130	137.88
8	123	123	147	150	148	137	136	129	136.63
Ave	120.75	124.75	146.50	153.63	150.75	137.0	134.25	130.88	136.63
SD	1.67	3.11	2.78	3.07	2.12	3.02	1.39	1.46	
CV	0.01	0.02	0.02	0.02	0.01	0.02	0.01	0.01	

Mechanical damage determination

Random samples of seed weight were collected from each row at the delivery tube. From each sample, an equal weight was taken, and both broken and unbroken seeds were counted for all selected samples to ascertain the number of broken and unbroken seeds. This procedure was conducted for all

selected PTO speeds to evaluate the percentage of mechanical damage caused by the fluted roller metering mechanism. The findings presented in the following Table 4 indicate that the visual seed damage observed was minimal, which aligns with the report by [1].

Table 4. Seed breakage percentage (%).

Replication	Percentage of broken seed							
	R1	R2	R3	R4	R5	R6	R7	R8
1	0.91	0.85	0.75	0.71	0.81	0.74	0.98	0.95
2	0.83	0.93	0.69	0.89	0.85	0.95	0.97	0.89
3	0.95	0.97	1.00	0.94	0.70	0.92	0.94	0.91
Average	0.90	0.92	0.81	0.85	0.78	0.87	0.96	0.92

Seed distribution uniformity

The analysis of variance revealed that the effect of PTO speed on seed distribution uniformity was highly significant, whereas the main effects of tractor forward speed and hopper loading did not demonstrate a statistically significant difference. As illustrated in Table 5 below, a higher PTO speed correlated with an increased plant population, while an increase in tractor forward speed resulted in a decrease in the

number of plants per square plot. Table 6 presents the interaction effects of PTO speed, forward speed, and hopper loading on seed distribution uniformity. The highest plant populations were recorded at PTO speeds of 1000 rpm combined with forward speeds of 6 km/hr, yielding 279 plants, respectively. Conversely, the lowest plant population of 77 was noted at a PTO speed of 540 rpm with full hopper loading and a forward speed of 6 km/hr.

Table 5. The main effects of PTO, tractor forward speed and hopper loading seed distribution uniformity.

PTO seeds (RPM)	Germinated seed population	Forward speed (km/hr)	Germinated seed population	Hopper loading	Germinated seed population
540	80a	4	181a	Half	178a
1000	276b	5	178a	Full	178a
		6	175a		
Significance	Sn **		Sn		Ns
LSD	3.754		4.598		3.754
CV (%)	5.5				
SD	1.89		2.32		1.89

Table 6. The combination effects of PTO, forward speed and hopper loading seed distribution uniformity.

Treatments	Treatments							
	Forward speeds (km/hr)			PTO seeds (RPM)	Hopper Loading	Forward speeds		
						4	5	6
PTO speeds RPM)	4	5	6	540	Half	88	85	66
540	84	85	72		Full	80	85	77
1000	279	271	279	1000	Half	271	270	287
					Full	287	271	270
LSD	6.50					9.20		
CV (%)	5.50					5.50		
SD	3.28					4.63		

The main Effect of PTO speeds Tractor forward speeds and Hopper loading on yield

The statistical analysis conducted through ANOVA demonstrated that the mean yield of the wheat planted was significantly influenced by PTO speeds ($P < 0.05$). Table 7 illustrates the impact of individual factors on the mean grain yield achieved with the wheat and fertilizer drilling machine.

According to the table, the highest grain yield of 6027 kg/ha was recorded at a PTO speed of 540 rpm, while the lowest yield of 5242 kg/ha was noted at elevated PTO operation speeds. Furthermore, it was observed that variations in tractor forward speeds and hopper loading did not have a significant effect on the grain yield.

Table 7. The main effects of PTO speeds, Tractor forward speed and hopper loading on grain yield.

PTO Speeds (rpm)	Yield (kg/ha)	Forward speed (km/hr)	Yield (kg/ha)	Hopper loading	Yield (kg/ha)
540	6027a	4	5674a	Half	5614a
1000	5242b	5	5491a	Full	5654a
		6	5738a		
LSD	317.4		388.7		317.4

PTO Speeds (rpm)	Yield (kg/ha)	Forward speed (km/hr)	Yield (kg/ha)	Hopper loading	Yield (kg/ha)
CV %	14.7				
Significance	Sn**		Ns		Ns

Combination effects of PTO, forward speeds and hopper loading on grain yields

Table 8 illustrates the impact of PTO speeds, tractor forward speeds, and hopper loading on the grain yield capacity of land cultivated with a drilling machine. The maximum grain yield recorded was 6641 kg/ha, achieved at a PTO

speed of 540 rpm, with half hopper loading and a tractor forward speed of 6 km/hr. Conversely, the minimum grain yield of 5034 kg/ha was observed at a PTO speed of 1000 rpm, full hopper loading, and a tractor forward speed of 5 km/hr.

Table 8. The combination effects of PTO speeds, tractor forward speeds and hopper loading on the harvested grain yield.

Treatments				
PTO seeds (RPM)	Hopper Loading	Forward speeds (km/hr)		
		4	5	6
540	Half	5603a	5900a	6641a
	Full	6541b	5806a	5669b
1000	Half	5241a	5221b	5081c
	Full	5313a	5034b	5563b
LSD	777.5			
CV (%)	14.7			
SD	391.7			

Field capacities of seed drilling machine

During the evaluation of field performance, various performance parameters, including theoretical field capacity, effective field capacity, and field efficiency, were examined and calculated, as presented in Table 9. The observations recorded from different plots indicate that the average theo-

retical field capacity, effective field capacity, and field efficiency of the drilling machine were 0.67 ha/hr, 0.55 ha/hr, and 81.78% at the first forward speed level; 0.84 ha/hr, 0.63 ha/hr, and 75.51% at the second forward speed level; and 1 ha/hr, 0.75 ha/hr, and 74.7% at the third forward speed level, respectively.

Table 9. The mean field performance parameters of the seed and fertilizer drilling.

Plot	Plot length (m)	Width (m)	Forward speed (km/hr)	Effective width (m)	Total Time (hr)	TFC (ha/hr)	EFC (ha/hr)	FE (%)
1	80.00	1.67	4.00	1.60	0.023	0.67	0.57	84.74
2	80.00	1.67	4.00	1.60	0.024	0.67	0.53	79.29
3	80.00	1.67	4.00	1.60	0.024	0.67	0.54	81.30
Average					0.02	0.67	0.55	81.78
1	80.00	1.67	5.00	1.60	0.022	0.84	0.59	70.89

Plot	Plot length (m)	Width (m)	Forward speed (km/hr)	Effective width (m)	Total Time (hr)	TFC (ha/hr)	EFC (ha/hr)	FE (%)
2	80.00	1.67	5.00	1.60	0.019	0.84	0.67	80.56
3	80.00	1.67	5.00	1.60	0.020	0.84	0.63	75.08
Average					0.02	0.84	0.63	75.51
1	80.00	1.67	6.00	1.60	0.018	1.00	0.71	70.75
2	80.00	1.67	6.00	1.60	0.017	1.00	0.76	75.39
3	80.00	1.67	6.00	1.60	0.016	1.00	0.78	77.95
Average					0.02	1.00	0.75	74.70

Seed drill agronomic performance parameters

According to agronomic guidelines, the recommended furrow width for planting irrigated wheat is 30 cm, with a row spacing of 20 cm. The planting depth should be adjusted based on specific requirements, as the machinery is equipped with adjustable settings. The optimal seeding depth for cereal crops, including wheat, barley, and oats, ranges from 3.75 to 5 cm. Planting wheat at this specified depth promotes effective

establishment and robust yields. As shown in Table 10 below, the row spacing was reduced due to the shear effect of the soil, and the ridge was disrupted following irrigation as a result of water erosion. Additionally, an increase in forward speed led to significant soil disturbance, resulting in a decrease in row spacing, with average measurements of 18.43 cm, 17.4 cm, and 16.37 cm at forward speeds of 4, 5, and 6 km/hr, respectively.

Table 10. Agronomic parameters determination for different forward speeds.

Forward speeds (km/hr)	Samples	Furrow width (cm)	Furrow depth (cm)	Row space (cm)	Plant strip width (cm)
4	1	27.3	11.3	18.5	4.1
	2	31.2	11.3	19.0	3.9
	3	31.8	11.3	17.8	4.2
Average		30.1	11.30	18.43	4.07
5	1	29.25	11.3	16.4	5.10
	2	30.8	11.3	18.2	4.25
	3	31.1	11.3	17.6	4.40
Average		30.1	11.30	17.4	4.58
6	1	31.2	11.3	14.3	6.1
	2	30.4	11.3	17.4	4.6
	3	30.4	11.3	17.4	4.6
Average		30.67	11.30	16.37	5.10

4. Conclusions and Recommendations

4.1. Conclusion

The study was conducted at Bako Agricultural Engineer-

ing Research Center to modify and evaluate the performance of tractor drawn wheat and fertilizer drill machine to PTO driven wheat fertilizer drilling machine.

Testing and performance evaluation were made to quantify the effects of PTO speed, tractor forward speeds and hopper loading level on theoretical field capacity, effective field capacity, row spacing, seed distribution uniformity and grain

yield. The optimum operating conditions were determined on the basis of measurements made and analysis carried out. The highest plant populations were recorded at PTO speeds of 1000 rpm combined with forward speeds of 6 km/hr, yielding 279 plants, respectively. Conversely, the lowest plant population of 77 was noted at a PTO speed of 540 rpm with full hopper loading and a forward speed of 6 km/hr. The maximum grain yield recorded was 6641 kg/ha, achieved at a PTO speed of 540 rpm, with half hopper loading and a tractor forward speed of 6 km/hr.

Conversely, the minimum grain yield of 5034 kg/ha was observed at a PTO speed of 1000 rpm, full hopper loading, and a tractor forward speed of 5 km/hr. The observations recorded from different plots indicate that the average theoretical field capacity, effective field capacity, and field efficiency of the drilling machine were 0.67 ha/hr, 0.55 ha/hr, and 81.78% at the first forward speed level; 0.84 ha/hr, 0.63 ha/hr, and 75.51% at the second forward speed level; and 1 ha/hr, 0.75 ha/hr, and 74.7% at the third forward speed level, respectively.

Operating at maximum PTO speed, combined with a high plant population, results in reduced yields due to increased competition for nutrients. Additionally, a forward speed exceeding 5 km/hr has been noted to yield low field efficiency, particularly when coupled with narrow row spacing and elevated seed rates.

4.2. Recommendation

The results indicate that the machine performs satisfactorily for both irrigated and conventional wheat and fertilizer drilling. Consequently, the following recommendations are proposed: -

- 1) To enhance the machine's field capacity and ensure compatibility with larger tractors, it is advisable to increase the width and the number of rows to exceed eight.
- 2) The fluted roller chamber should be replaced with a cast iron version, as there is a risk of rusting due to moisture in the fertilizer post-plantation.
- 3) Proper land preparation is essential; the soil must be plowed and harrowed to the recommended depth prior to operating the machine to facilitate effective furrow and row management.
- 4) The existing furrow opener shank, currently constructed from a square pipe, should be substituted with a flat bar of at least 8 mm thickness.
- 5) The seed and fertilizer drilling machine highly recommended to extension worker for dissemination and popularization to end users.

Abbreviations

AAERC Asella Agricultural Engineering Research Center

ANOVA	Analysis of Variance
CV	Coefficient of Variation
LSD	Least Significance Difference
PTO	Power Take off
RPM	Revolution Per Minute
SD	Standard Deviation
SNNP	South Nation Nationality and People

Author Contributions

Merga Workesa: Investigation, Methodology, Project administration, Software, Supervision, Validation, Writing – original draft, Writing – review & editing

Matiwos Belina: Conceptualization, Data curation

Solomon Lemmessa: Conceptualization, Supervision, Validation

Conflicts of Interest

The authors declare no conflicts of interest.

References

- [1] Abulasan Kabaradin. 2023. "On-Farm Evaluation of Tractor Drawn Wheat Seed Drill." *International Journal of Precision Farming* 1(1).
<https://doi.org/10.29322/ijsrp.9.02.2019.p8658>
- [2] A. R. Bentley, J. Donovan, K. Sonder, F. Baudron, J. M. Lewis, 2022. Near-to long-term measures to stabilize global wheat supplies and food security *Nature Food*, 3(7), pp. 483-486.
- [3] D. Karayel, and A. Özmerzi. 2008. "Evaluation of Three Depth-Control Components on Seed Placement Accuracy and Emergence for a Precision Planter." *Applied Engineering in Agriculture* 24 (3): 271-76.
<https://doi.org/10.13031/2013.24494>
- [4] M. Reynolds, J. Foulkes, R. Furbank, S. Griffiths, J. King, 2012. Achieving yield gains in wheat *Plant Cell Environ.*, 35(10), pp. 1799-1823.
- [5] FAOSTAT, 2018. Data, crops. Database of Agricultural Production. Food and Agriculture Organization of the United Nations, Available from:
<http://faostat.fao.org/default.aspx>
- [6] Van Ittersum, M. K., Van Bussel, L. G., Wolf, J., Grassini, P., Van Wart, J., Guilpart, N., Claessens, L., De Groot, H., Wiebe, K., Mason-D'Croz, D. and Yang, H., 2016. Can sub-Saharan Africa feed itself?. *Proceedings of the National Academy of Sciences*, 113(52), pp. 14964-14969.
- [7] Kannan, A, V M Martin Vimal, A Madesh, and S Karthick. 2015. "DESIGN AND FABRICATION OF MULTIPURPOSE SOWING MACHINE." *International Journal of Scientific Engineering and Applied Science (IJSEAS)*, no. 1.
www.ijseas.com

- [8] van Ittersum, M. K. and Rabbinge, R., 1997. Concepts in production ecology for analysis and quantification of agricultural input-output combinations. *Field crops research*, 52(3), pp. 197-208.
- [9] Kwanchai A. Gomez, Arturo A. Gomez. Statistical Procedures for Agricultural Research, 2nd Edition. International Journal of Precision Farming. E-palli.
<https://doi.org/10.54536/ijpf.v1i1.2175>
- [10] M, Ibrahim M, and A Farag. 2008. "Developing a Multi Purpose Digger for Harvesting Root Crops."
- [11] Senbeta, A. F., Supit, I. and Harahagazwe, D., 2021. Sensitivity of potato yield and biomass to climate change effects in Gisozi, Burundi, and Washington, USA, and assessment of LINTUL4 model behavior. *Journal of Agriculture and Environment for International Development (JAEID)*, 115(1), pp. 5-30.
- [12] Villalobos, F. J., Orgaz, F. and Fereres, E., 2017. Sowing and planting. In *Principles of agronomy for sustainable agriculture* (pp. 217-227). Cham: Springer International Publishing.
- Simson, Reijo. 2016. "The Effect of Fertilizer and Growing Season on Tuber Dry Matter and Nitrate Content in Potato."
<https://www.researchgate.net/publication/311222049>
- [13] Abiy Solomon. 2017. "Performance Evaluation of Walking Tractor Drawn Wheat Planter."Ethiopia. Acad. Res. J. Agri. Sci. Res 5(7): 529-38.
<https://doi.org/10.14662/ARJASR2017.084>
- [14] Salter, P. J., 1985. Crop establishment: recent research and trends in commercial practice. *Scientific Horticulture*, 36, pp. 32-47.
- [15] Tufa, Tolcha, Haji Kumbi, and Tolera Abera. 2020. "Influence of Seed Rate and Row Spacing on Growth and Yield of Bread Wheat in Chelia District of West Showa Zone." Ethiopia Article in Open Journal of Natural Science.
<https://doi.org/10.7176/JNSR>
- [16] World Food and Agriculture - Statistical Yearbook 2023. 2023. World Food and Agriculture - Statistical Yearbook 2023. FAO. <https://doi.org/10.4060/cc8166en>
- [17] Gosa B. and Ayalew B. 2019. Fabrication and Evaluation of Tractor Drawn Wheat Row Planter. International Journal of Scientific and Research Publications 9(2): p8658.
- [18] Yagmur, Mehmet, and Digidem Kaydan. 2009. "The effects of different sowing depth on grain yield and some grain yield components in wheat (*Triticum aestivum* L.) cultivars under dryland conditions." *African Journal of Biotechnology* 8.2.