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Performance Evaluation of Tractor-Drawn Wheat Seed Drill

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ABSTRACT

A staple food in one-third of the world's population, wheat is one of the most significant cereal crops. Sub-Saharan Africa's top producer of wheat is Ethiopia. In terms of area coverage, wheat comes in fourth place behind maize (Zea mays), sorghum (Sorghum bicolor), and teff. It comes in second place behind maize in terms of total production and productivity. The purpose of this study was to design, develop, and assess the performance of a prototype seed drill that could apply fertilizer and sow wheat seeds at specific depths and row spacing. Row spacing, depth of seed placement, plant count/stand, field capacity, field efficiency, labor cost, and economics of owning and operating were all taken into consideration when evaluating the performances. A randomized complete block design was employed for the experiment, which included three replications, three hopper fill levels, and three operating speeds. It showed that, when compared to the germination percentage of the seed suggested by the seed supplier, there was no decrease in the percentage of visible and invisible mechanically damaged seed by the seed drill for any variety. In accordance with wheat agronomic requirements, the seed and fertilizer rates were calibrated at 125 kg/ha and 150 kg/ha, respectively, for 20 cm row spacing and 5 cm depth. The seed drill was tested with hopper filling levels of H50, H75, and H100 and speeds of 3, 4, and 5 km/h. The seed and fertilizer rate was significantly affected by the seed drill's forward speed and hopper filling capacity at $p < 0.05$. The optimum operating speed must be kept to a minimum of 3 km/h. At a speed of 4 km/h, the average field capacity, field efficiency, and fuel consumption were 0.36 ha/hr, 76.80%, and 4.76 l/hr. During the field germination count, there were between 375 and 379 plants per 1.2 m2 area. The majority of farmers can use the developed seed drill effectively, economically, and efficiently, according to the results of the performance evaluation.

INTRODUCTION

According to many claims made by demographers and agricultural experts, Ethiopia could become self-sufficient in food, feed, and fiber if the current agricultural production factors were properly utilized. Nonetheless, a variety of factors may influence the increase in agricultural output and productivity. The three primary ones are the adoption of contemporary farming technologies, the modernization of farming practices through the use of improved farm equipment, and the growing utilization of contemporary farm inputs.

One of the most important cereal crops in the world, wheat is a staple food for one-third of the world's population (Hussain & Shah, 2002). Ethiopia is the biggest producer of wheat in sub-Saharan Africa.

Wheat ranks fourth in terms of overall output and productivity, behind teff, sorghum (Sorghum bicolor), and maize (Zea mays), and second only to maize in terms of area coverage. The primary wheat-growing regions in Ethiopia are the highlands in the country's central, southeast, and northwest regions, which average 1.80 million hectares per year. Wheat is produced regionally by 4.7 million farmers with a productivity of 2.4 tons per hectare, as well as by Oromia (57.4%), Amhara (27%), SNNP (8.7%), and Tigray (6.2%) (CSA, 2014). Despite being the primary food crop for the majority of the population, the country produces only 40q/ha of wheat, which is less than other wheat-producing countries (FAO, 2009).

The crop's low production and productivity can be explained by conventional farming methods, reliance on rainfall, and the limited use of improved agricultural inputs (mechanical and biological). The inefficiency of the nation's traditional farming system is the primary reason for the low level of production. Aware of this fact, efforts have been made to boost wheat productivity and production through the agricultural extension system. Farmers have put a lot of effort into improving their methods, but the lack of suitable equipment for row planting made the effort pointless.

Different design approaches were used to create a range of wheat row seeders, each with their own advantages and disadvantages, in order to address the aforementioned problem.

In 2015, Ashebir Tsegaye evaluated a two-row animal-drawn multi-crop planter with three hopper loading levels, three seed types, and three forward speed levels (3, 5, and 7 km/hr) with three replications. The results show that the combined effect of forward speed and hopper-filling level on the percentage of seeds across several indexes was significant ($P < 0.05$) for all seeds at a forward speed of 7 km/h.

A two-wheel tractor-drawn wheat seed six-row drill machine was evaluated by Abiy Solomon (2017) in three

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replications at three forward speeds (1.4, 2, and 2.5 km/h) and hopper fillings (full, 3/4, and half). For a number of observations, he came to the conclusion that the hopper filling level had an impact on the wheat seed rate.

Thus, the goal of this study is to test and evaluate the performance of the tractor-drawn wheat seed drill. The main drawback that has been identified so far is that current wheat seed drills are unable to maintain consistent seeding rates, fertilizer and seed application simultaneously, and even seed delivery because of poor design and manufacturing.

MATERIAL AND METHODS

Performance Test and Evaluation

Before the performance test, a preliminary test run was conducted to check for any flaws or malfunctioning parts and to see if the machine was functioning as intended. As a result, the prototype seed drill performed its intended function efficiently and with good stability.

Two sets of tests were carried out: laboratory research was done to calibrate the machine in terms of seed rate and seed damage, and field tests were carried out to ascertain the machine's actual overall performance.

Laboratory Performance Test

Mechanical Damage Test

To check for percentage seed damage, the seeder was held (raised up) while the seeds were being loaded into the hopper. The wheel made ten full rotations. It was looked for any external damage on the seeds that were released from the seed tube. The number of damaged seeds that were collected and inspected individually was weighed after the seeds that had been clearly damaged during the calibration were identified. The percentage damage was then calculated as follows (Rangapara, 2014).

$$\%\ damage = W_s / W_{ts} \qquad (1)$$

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

Seed Distribution Test

In order to determine the rate of seed discharge at forward speeds of 3, 4, and 5 km/hr, the machine was evaluated both in the laboratory and in the field. The machine's seed hopper was filled to half, three-fourth and full capacity. Over a 100-meter track test, a 25-hp tractor pulled the seed drilling machine at predetermined forward speeds and hopper loading to assess the uniformity of the seeds. To collect the seeds released during the test run, seed collecting bags were placed beneath each seed tube. After every test run, a balance was used to weigh and compare the seeds in the bags for each furrow opener.

Seed Germination Test

Before testing, the Ethiopian seed enterprise assessed the germination potential of each wheat variety. The test was intended to ascertain whether any internal seeds had been harmed by the seed drill machine. Each variety's 100 wheat seeds were extracted from a seed drill and placed in a petri dish. The germination percentage was calculated by counting the number of seeds that sprouted after eight days (Rangapara, 2014).

$$Ger\ min\ action\ (\%) = N_{sg} / N_{sp} \qquad (2)$$

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

Field Test

Well-prepared and harrowed soil was used for field testing. There was a seed drill on the tractor. Based on the parameters acquired during laboratory studies, the developed prototype was operated at three different operating speeds 3, 4, and 5 km/h and three different hopper loading levels. It was noted how different operating speeds affected seed rate, seed uniformity, and seed damage. The field test measured a number of performance parameters, including uniformity of seed distribution, labor requirement, plant population, field efficiency, field effective capacity, and time using a stopwatch.

Soil Parameters

Moisture Content of Soil

Soil samples were collected 20 cm below the soil surface before procedures to measure the bulk density and moisture content were conducted. Five randomly selected samples were taken from the test plots. The samples were kept in an oven set to 105°C for 24 hours and weighed both before and after drying. In 2014, Rangapara determined the moisture content (Db).

$$MC = ((M_w - M_d)/M_d) * 100 \qquad (3)$$

Where, MC= moisture content, M_w= mass of wet soil sample, and M_d = mass of dry soil sample

Bulk Density of Soil

The core sampler was used to gather samples from the field. The bulk density of the soil was determined using the dry weight of the sample and the volume of the soil samples. It was used to determine the bulk density of soil (Rangapara, 2014).

$$BDS\ (g/cm^3) = Md/Vs \qquad (4)$$

Where, BDS= bulk density of soil; M_d=mass of dry sample (g); Vs=volume of core sampler (cm^3)

Machine Performance Parameters

Operating Speed

The seed-drilling machine's operating speed was calculated by timing how long it took to go 20 meters using a stopwatch.

$$V = D/t_a \qquad (5)$$

Where: - V = Working speed, D = distance of run (m), t_a = average time of each pass (second)

Theoretical Field Capacity

The rate at which the implement covers 100% of its rated width and 100% of its rated speed is known as its theoretical field capacity.

$$TFC\ (ha/hr) = (Width(m) * Speed(Km/hr))/10 \qquad (6)$$

Effective Field Capacity

In accordance with Kepner's (1978) advice, field capacity and efficiency were computed using relevant parameters, including effective operation time, turning time, and time losses from field obstructions. A 10 m by 20 m plot that required, on average, eight passes with a width of 1.2 m was used to assess field capacity and efficiency.

Effective field capacity (ha/h) =(Actual Area covered (ha))/(time required to cover(h)) (7)

Field Efficiency

FE(%) = (EFC/TFC) * 100 (8)

Fuel Consumption

Fuel consumption was measured using a graduated cylinder in accordance with standard practice. A known volume of fuel was refilled after the fuel tank was filled to capacity prior to the test run. Fuel consumption per plot was then calculated by subtracting the amount of fuel used.

The following formula was used to estimate and observe the fuel consumption (l):

Fuel consumption (l/ha) = (Fuel Consumption (l))/(Area Covered (ha)) (9)

Draft and Power Requirement

The draft was measured using a dynamometer attached to the tractor that the tool was mounted on. Another auxiliary tractor pulled the implement-mounted tractor through the dynamometer. The auxiliary tractor pulls the implement-mounted tractor when the latter is in neutral gear and the implement is in the operating position. Draft was measured at a distance of 20 meters. On the same field, the draft was seen after the instrument was lifted off the ground. According to Rangapara (2014), the implement's draft is based on the discrepancy between the two readings.

Figure 1: Draft measurement

Draft (KN) = DI - Du (10)

Where, D_l = draft of under loaded condition, D_U = draft of under unloaded condition

The tractor power consumption was also determined by following formula:

power W = Draft (N) * speed(m/s) (11)

Wheel Slip

When the ground wheels lose their traction, it's called slippage and can cause uncontrollable movement. Two stakes with flags 20 meters apart were used to mark the test path on the field. A paint mark was made on the wheel to facilitate counting the number of revolutions required to travel the distance between two flags. The number of wheel revolutions required to move the machine 20 meters without any load was counted while it was operating. The number of wheel revolutions required to travel the same distance under load was determined for the next test run. Throughout the experiment's five iterations, data was recorded. The drive wheel slip was calculated using the following formula (Nirala, 2011).

Wheelslip= (A-B/A) * 100 (12)

Where, A = number of turns of wheel without load, B = number of turns of wheel with load

Row to Row Spacing

Before planting, furrow openers were fastened to the machine's frame using bolts and nuts to change the row spacing. In the field, the wheat seed drill was used on well-prepared and harrowed soil. Using meter tape, five random measurements of the actual row-to-row spacing were taken while the wheat seed drill was operating.

Depth of Seed Placement

To adjust the depth of seed and fertilizer placement, the furrow opener was raised or lowered to the desired depth of 5 cm on a level surface prior to planting. The seed drill was used in pulverized soil in the field. A 10-meter-long section of soil was carefully removed without disturbing the seeds and fertilizers. The depth of seed and fertilizer placement was then measured using a metering tape and graduated ruler. Five readings for each of the six furrow openers from the test plot were chosen at random.

Plant Population and Uniformity

The number of plants in each treatment's area was counted, and observations were made at randomly selected spots per square meter. In order to determine the variation between the rows, the plant uniformity test was conducted by calculating the average number of seedlings that emerged in each row at a distance of one meter.

Economic Evaluation

The annual and hourly operating costs of the tractor and the developed seed drill were estimated using the following factors: depreciation, labor costs, interest on capital, the cost of repairs and replacement parts, and the tractor's capital cost. The operational cost components of the prototype 25-hp tractor and seed drill were estimated by Wen-yuan Huang *et al.* (1979) in Birr (EB). The seed drill is expected to be used 425 hours a year, while the tractor is assumed to have an economic life of ten years and 850 hours per year.

Table 1: Annual and hourly operational costs of the Tractor and fabricated planter

No.	Cost estimation	Formula Used	Sources
	I. Fixed Cost		
2.13	Depreciation	DP= ((PP -SV)/(L*H)), (EB/h)	(Kepener *et al.*, 1987)
2.14	Interest	I= (PP+SV/2) * (I%/H), (EB/h)	(Kepener *et al.*, 1987)
2.15	Insurance & taxes (IT)	IT= 1% of PP	(Kepener *et al.*, 1987)
2.16	Housing	Housing= 1% of PP	(Kepener *et al.*, 1987)
2.17	Total fixed cost	D_p + I + IT + Housing g	(Kepener *et al.*, 1987)
	I.Variable cost		(Kepener *et al.*, 1987)
2.18	Repair and maintenance cost	RM= 10% of PP	(Kepener *et al.*, 1987)
2.19	Total cost per hour	Fixed cost t/hr + Variable cos t/hr	(Kepener *et al.*, 1987)

Where, Purchase price (Pp): 123,000 EB, Salvage value (SV): 10%, Interest rate: 10 %, Repair and maintenance (RM): 10% , Insurance & taxes (IT): 1% of PP, Housing: 1 % of PP, Fuel consumption: 3.46 lit/hour , FC = 18.10 EB per lit Lubrication cost (L.C): 140 EB per lit, Lubrication consumption: 25% of fuel ,Labor cost (LaC): 150 EB per day and Dp = Depreciation

Experimental Design

Three replications and a randomized complete block design comprised the factorial experimental design. Three hopper loading levels and three seed drill forward speed levels were employed as treatments, each with three replications. There were a total of 27 test runs in the experimental design, which was set up as 3^2 with three replications (3x3x3 = 27).

Three replications and a randomized complete block design comprised the factorial experimental design. Three replications of each treatment three hopper-loading levels and three seed drill forward speed levels were used. There were 27 test runs (3x3x3 = 27) and 3^2 replications in the experimental design.

Statistical Analysis

Analysis of variances was performed on the data using GenStat 15th edition statistical software and a protocol appropriate for the experiment's design (Gomez and Gomez, 1984). Treatment means that differed at 5% levels of significance were separated using the least significant difference (LSD 5%) test. The least significant difference (LSD) test was used to examine the mean values of actual seed and fertilizer application rates in relation to forward speed and hopper level of filling.

RESULTS AND DISCUSSION

Laboratory Test

Seed Drill Calibration Test

Prior to actual data collection, the developed tractor-operated wheat seed drill machine was calibrated to ascertain the seed and fertilizer rate of the machine and to observe variations in rates among furrow openers. Tables B.1 and B.2 in Appendix-B provide detailed calibration observations. The weights of the seeds and fertilizer that were taken from each furrow opener ranged from 124.1 to 125.7 kg/ha and 149.7 to 150.2 kg/ha, respectively, according to the data. These demonstrate that the observed rates of fertilizer and seeds were almost identical to the rates suggested by researchers and experts, which were 150 kg/ha for fertilizer and 125 kg/ha for wheat seeds, respectively. The seed and fertilizer rates for the five replications, which ranged from 0.59 to 2.28 percent and 0.36 to 1.47%, respectively, showed no discernible coefficient of variation.

Mechanical Damage Test

According to Table 2, which displays visual observations for mechanical damage caused by the metering mechanism, there was no discernible damage to the seeds at any of the selected speeds because of the adjustable flap curvature, which reduces friction and impact between the seeds and the fluted roller. Similar findings were reported by Pradhan and Ghoshal (2012). The seed germination test was also conducted, and the outcomes were documented. By planting 100 seeds in steel trays (a petri dish), the internal damage of the seeds was evaluated and the germination of the seeds was tested both before and after metering. The findings demonstrated that there was no internal seed damage, suggesting that the 99 percent germination potential that was observed was in line with the predictions made by the seed supplier (Ethiopian Seed Enterprise, Asalla branch).

Table 2: Data obtained from laboratory test of the seed drill machine

Observations	Speed, km/h	Seed rate obtained, kg/ha	Mechanical damage, %	Germination %
1	3	126.76	0.0	99
2	4	123.85	0.0	99
3	5	121.60	0.0	99

Seed Distribution Test

Table 3 shows the variations in the distribution of wheat seeds (furrow openers) among the rows. With minimal variation between samples (0.28–1.20) and a coefficient of variation ranging from 0.11 to 0.47, it was discovered that every sample collected for the same speed and hopper filling was nearly the same.

Table 3: Seed mass dropped from each furrow opener along a 100-meter length at varying speeds and hopper filling capacities

		mass of seeds from each furrow opener per 100m length, gm						
Speed	**H.filling**	**F1**	**F2**	**F3**	**F4**	**F5**	**F6**	**CV**
3	50 %	256.40 ± 0.68	255.43 ±0.25	254.90 ± 0.01	253.27 ± 0.71	255.03 ± 0.07	254.17 ± 0.31	0.42
	75 %	256.17 ± 0.88	253.80 ± 0.18	253.77 ± 0.22	253.27 ± 0.42	254.97 ± 0.34	253.27 ± 0.42	0.45
	100 %	255.87 ± 1.05	253.33 ± 0.08	253.30 ± 0.09	253.00 ± 0.23	253.13 ± 0.17	252.43 ± 0.48	0.47
4	50 %	249.13 ± 0.15	249.80 ± 0.45	248.67 ± 0.05	248.20 ± 0.26	248.47 ± 0.14	248.50 ± 0.13	0.23
	75 %	247.87 ± 0.12	248.33 ± 0.09	248.23 ± 0.04	248.23 ± 0.04	248.43 ± 0.13	247.70 ± 0.19	0.12
	100 %	248.00 ± 0.13	247.60 ± 0.05	248.07 ± 0.16	247.47 ± 0.11	247.70 ± 0.004	247.40 ± 0.14	0.11
5	50 %	243.77 ± 0.71	245.80 ± 0.20	246.10 ± 0.33	246.43 ± 0.48	245.33 ± 0.01	244.67 ± 0.30	0.40
	75 %	243.33 ± 0.17	244.20 ± 0.22	242.93 ± 0.35	243.73 ± 0.01	244.33 ± 0.28	243.70 ± 0.001	0.22
	100 %	244.20 ± 0.44	243.60 ± 0.17	242.33 ± 0.40	242.97 ± 0.11	243.20 ± 0.004	242.97 ± 0.11	0.26

Effects of Seed Drill Operating Speed on Seed Rate

The analysis of variance (ANOVA) in Appendix table B.3 revealed that the seed drill forward speed and hoper loading level had a significant effect ($p < 0.05$) on wheat seed rate, but the interaction between hoper loading level and seed drill forward speed had no significant effect (p >

Table 4: Effects of seed drill operating speed and hopper filling level on seed rate

<table>
<tr><th>Parameter</th><th colspan="4">Source of variation</th><th colspan="2">Measure of differences</th></tr>
<tr><td rowspan="15">Seed rate (Kg/ha)</td><td>Speed level</td><td colspan="3">Seed rate</td><td>LSD (5%)</td><td>SE(M)</td></tr>
<tr><td>V_3</td><td colspan="3">127.1[a]</td><td rowspan="3">0.20</td><td rowspan="3">0.07</td></tr>
<tr><td>V_4</td><td colspan="3">124.1[b]</td></tr>
<tr><td>V_5</td><td colspan="3">122.0[c]</td></tr>
<tr><td colspan="6">Hopper filling level</td></tr>
<tr><td>H_{50}</td><td colspan="3">124.8[c]</td><td rowspan="3">0.20</td><td rowspan="3">0.07</td></tr>
<tr><td>H_{75}</td><td colspan="3">124.3[b]</td></tr>
<tr><td>H_{100}</td><td colspan="3">124.1[a]</td></tr>
<tr><td colspan="6">Interaction(V*H)</td></tr>
<tr><td>Speed level</td><td>H_{50}</td><td>H_{75}</td><td>H_{100}</td><td rowspan="4">0.35</td><td rowspan="4">0.12</td></tr>
<tr><td>V_3</td><td>127.4[a]</td><td>127.1[a]</td><td>126.8[a]</td></tr>
<tr><td>V_4</td><td>124.4[b]</td><td>124.1[bc]</td><td>123.9[bd]</td></tr>
<tr><td>V_5</td><td>122.7[c]</td><td>121.9[de]</td><td>121.6[df]</td></tr>
</table>

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

0.05). Table 4 shows the effects of operating speed, hopper loading capacity, and the combination of hopper filling and speed level on wheat seed rate. Figure 2 shows the correlation between seed drill linear speed and seed rate.

When the hopper filling level was increased from H50 (half) to H100 (full) and the operating speed was increased from 3 to 5 km/h, the seed rates were declining. However, the combination of Operational speed and hopper filling capacity did not have significant effect on seed rates.

The highest seed rate of 127.4 kg/ha was recorded at a forward speed of 3 km/h and a half hopper loading capacity. The lowest seed rate, 121.6 kg/ha, was attained at a speed of 5 km/h and full hopper loading capacity. This made it abundantly evident that a lower seed rate would occur at forward speeds greater than 5 km/h. Forward speeds below 3 km/h, however, would produce a higher seed rate, exceeding the recommended 125 kg/ha of wheat seeds (informal communication with experts).

However, the combined effect of operational speed and hopper filling level did not significantly affect seed rate, as Table 4 demonstrates. Overall, forward speed and the amount of seed in the hopper had a significant impact on seed rate. Nevertheless, it is clear that the effect was caused more by the variations in filling speeds and levels than by their combination.

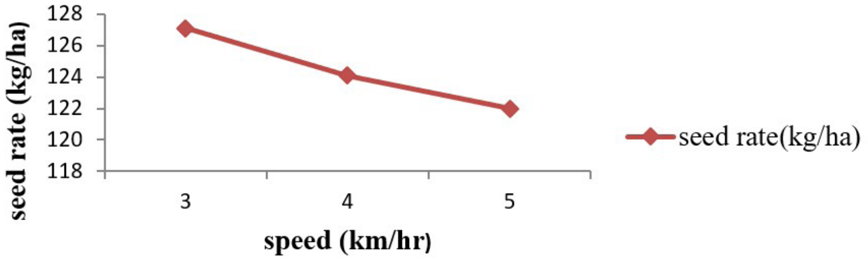

Figure 2: Effects of seed drill linear speed on wheat seed rate

Effects of Seed Drill Operating Speed on Fertilizer Rate

The fertilizer application rate was significantly ($p < 0.05$) influenced by the seed drill forward speed and hoper loading level, but not significantly ($p > 0.05$) by the combination of the two variables, according to the analysis of variance (ANOVA) results in appendix table B.4. Table 5 illustrates how fertilizer rate is affected by hopper loading capacity, operating speed, and the combined effects of hopper filling level and speed. Figure 3 shows the relationship between seed drill linear speed and fertilizer application rate.

Table 5: Effects of seed drill operating speed and hopper filling level on fertilizer application rate

Parameter	Source of variation				Measure of differences	
	Speed level	**fertilizer rate**			**LSD (5%)**	**SE(M)**
Fertilizers application rate (Kg/ha)	V_3	152.1^{a}			0.12	0.04
	V_4	148.7^{b}				
	V_5	146.2^{c}				
	Hopper filling level					
	H_{50}	149.4^{c}			0.12	0.04
	H_{75}	148.9^{b}				
	H_{100}	148.7^{a}				
	Interaction(V*H)					
	Speed level	**H50**	**H75**	**H100**	0.20	0.07
	V_3	152.7^{a}	152.1^{b}	151.7^{c}		
	V_4	149.0^{b}	148.6^{cd}	148.4^{a}		
	V_5	146.6^{c}	146.2^{a}	146.0^{b}		

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

When operating speed is increased from 3 to 5 km/h and hopper filling level is increased from H50 (half) to H100 (full), fertilizer application rates typically decrease. However, there was not a significant impact of their combination on application rates.

At a forward speed of 3 km/h and a half-hopper loading capacity, 152.7 kg/ha was the highest application rate recorded. However, the lowest application rate of 146 kg/ha was attained at a speed of 5 km/h and full hopper loading capacity. This clearly demonstrated that application rates would be lower at forward speeds greater than 5 km/h and higher at forward speeds less than 3 km/h, exceeding the recommended NPS fertilizer rate of 150 kg/ha (informal communication with experts).

However, the combined effect of operational speed and hopper filling level did not significantly affect application rate, as Table 5 demonstrates. In general, the amount of fertilizer particles in the hopper and forward speed had a significant impact on application rate. Nevertheless, it is clear that the effect was caused more by the variations in speeds and hoper filling levels than by their combination.

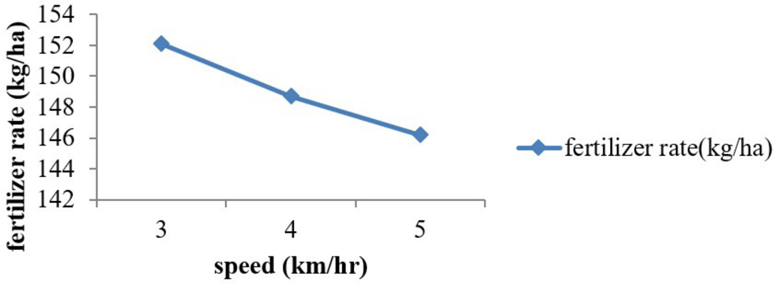

Figure 3: Effects of seed drill linear speed on fertilizer rate

Field Test

The mechanical and functional capabilities of the seed drill were evaluated in a field area of 10 x 20 m^2 in the Eteya district on farmers' farmland. For the study, a variety of wheat called Danda'a was sown. Wheat was sown in the field with a 20 cm row-to-row spacing.

Moisture Content of Soil

Five soil samples, each 20 cm below the soil's surface, were chosen at random from the field. Appendix table 5 shows that the average moisture content at a depth of 20 cm was 17.60% on a dry basis.

Bulk Density of Soil Sample

A core cutter with a volume of 384.85 cm^3 was used to calculate the soil sample's bulk density. Prior to being kept in an oven set at 105 °C for 24 hours, the sample was first weighed. After drying, the sample's weight was again measured. The average bulk density for the experimental field was 1.42 g/cm^3, as shown in Appendix table 5.

Operating Speed

On the speed limit, the operating speed was kept at 3 km/h, 4 km/h, and 5 km/h Appendix Table 6. The speed was measured using a stopwatch device. A higher seed and fertilizer rate was obtained by determining that the tractor-drawn seed drill's optimum operating speed for planting particular seeds was 4 km/h over a 20-meter distance.

Theoretical and Effective Field Capacity of Seed Drill

The average theoretical field capacity of the seed drill was 0.37, 0.49, and 0.6 ha/hr at 3, 4, and 5 km/hr. At the same speed levels of 3, 4, and 5 km/h, the effective field capacity was also found to be 0.31, 0.36, and 0.45 ha/hr Appendix table 6. The theoretical and effective field capacities of the seed drill increased with increasing speed, as shown in Figure 4 In general, this means that a seed drill can plant a hectare of land in 2.22 to 3.22 working hours, depending on operating speed.

Field Efficiency

The average field efficiency values obtained were listed in Appendix table 6. The operating speed of 5 km/h yielded the lowest field efficiency of 75.51%, while the operating speed of 3 km/h yielded the highest efficiency of 80.48%. Figure 5 illustrates how field efficiency dropped with increasing speed. According to Rangapara (2014), the number of drill passes increased along with the field size reduction, leading to higher time losses and lower

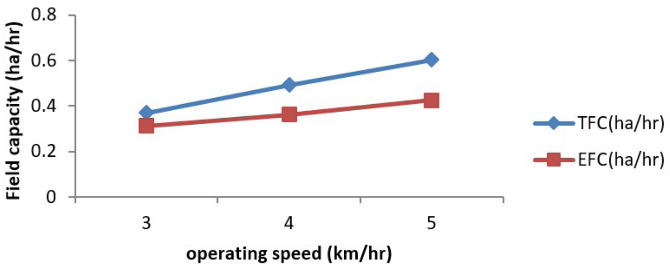

Figure 4: Effects of seed drill linear speed on theoretical and effective field capacity

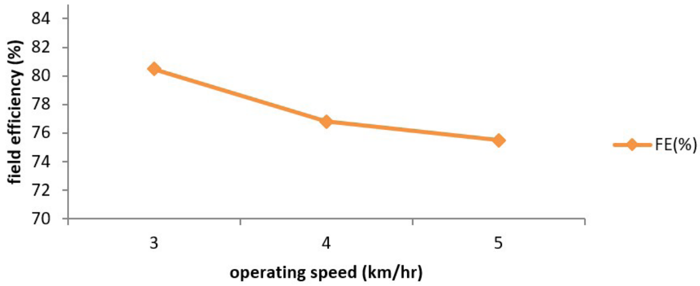

Figure 5: Effects of seed drill linear speed on field efficiency

field efficiency values. The main factor contributing to the reduction in field efficiency brought on by increasing forward speed was the theoretical time consumed, which was less than that of the other test plots.

Fuel consumption

Operating speed results showed that average fuel consumption increased with speed Appendix table 6. At 3, 4, and 5 kilometers per hour, the average fuel consumption during operation was 3.46, 4.76, and 6.69 liters per hour, respectively.

Draft and power requirement

The draft required to operate the developed seed drill was measured using a spring dynamometer. The average draft values were 454.80, 466.80, and 474.00 N at 3, 4, and 5 km/h, respectively (Appendix table B.7). The minimum draft was 454.80 N at 3 km/h, and the maximum draft was 474 at 5 km/h. additionally, the power required to operate the developed seed drill was calculated based on operating speed and the draft required to run the drill. The power requirements were found to be 0.51, 0.69, and 0.88 horsepower at 3, 4, and 5 km/h, respectively. The observed pattern of draft and power requirements is shown in Figure 6 It is clear from the figure that the draft and power required to operate the developed seed drill increase with operating speed.

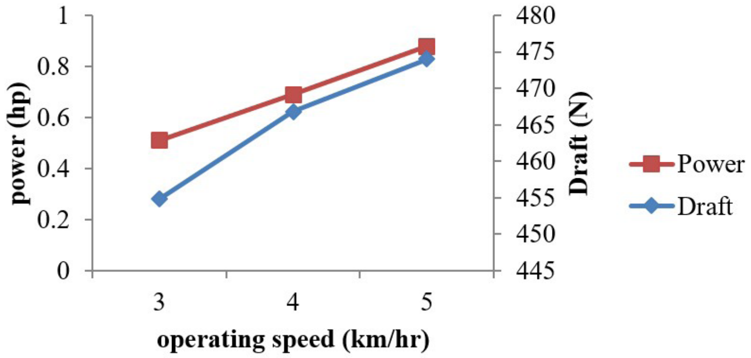

Figure 6: Effect of speed on draft and power requirement

Wheel Slip

A tractor-drawn seed drill's wheel slip was measured using the previously mentioned technique. Appendix Table B.8 shows the results for wheel slip data at different operating speeds. The minimum wheel slip percentage was 3.56% and the maximum was 5.28% at 3 km/h and 5 km/h, respectively. Figure 7 shows a slight increase in wheel slip as speed increased.

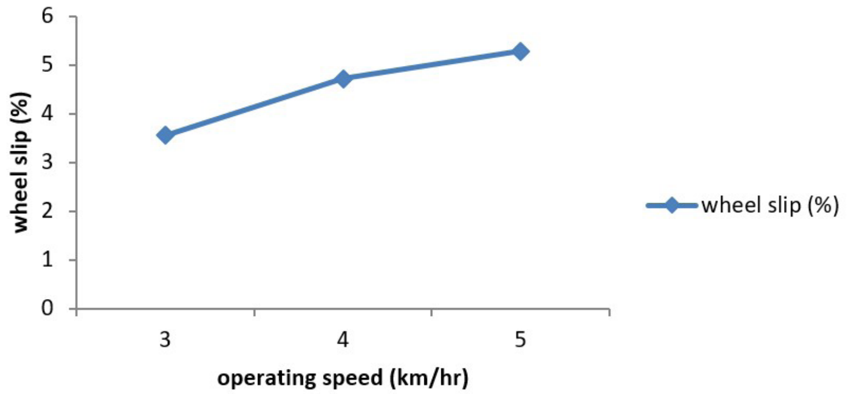

Figure 7: Effect of speed on ground wheel slippage

Row to Row Spacing

To achieve the recommended 20 cm wheat row spacing, all furrow openers were kept fixed on the main frame at a distance of 20 cm from one another. In the field, the wheat seed drill was used on well-prepared and harrowed soil. It is unaffected by forward speed, and the same result was obtained when row-to-row spacing varied between 20.0 and 20.5 cm.

Figure 8: Row spacing measurements

Depth of Seeds and Fertilizer Placement

The furrow openers were attached to a single hollow square pipe with bolts and nuts, so the depth at which seeds and fertilizer were placed could be adjusted by raising or lowering the furrow opener. Measurements and observations of the seed and fertilizer placement were made in the field, and it was discovered that 4.84 cm was nearly equal to the desired depth of 5 cm. Fertilizers were applied using the side dressing method.

Plant Population and Uniformity

A field count of the plant population was carried out in accordance with the methodology. After ten and fifteen days of sowing the Danda'a wheat variety, which has a 99.7% germination potential (Ethiopian seed enterprise, Asalla branch), the number of seeds that germinated per 1.2 m^2 area is shown in Appendix table 9. The metering mechanism accurately and damage-free meters the seeds, as demonstrated by the observed seed rate and plant population per 1.2 m^2. The recommended and actual seed emergence in the field did differ in a few ways, though, and these variations might have been caused by environmental factors.

Economical Evaluation

The tractor-drawn seed drill machine only required one operator. A single person using a tractor-drawn seed drill machine only required 3.22 to 2.22 hours per hectare, operating at a speed of 3 to 5 km/hr, whereas a single person using an animal-drawn planter required 8.33 hours per hectare to plant and fertilize a hectare of land (Ashebir, 2015). Therefore, the time required per hectare is three times shorter when using a tractor-drawn seed drill at 5 km/h than when using an animal-drawn planter.

Summary

Designing, developing, and testing a seed drill that could plant wheat seeds and apply fertilizer at exact depths and spacing was the aim of this study. The physical properties of the seeds and fertilizers used in the study were investigated in order to enhance the design of the seed drill components.

Hidase, Danda'a, Ogolcho, Digelu, and Kekeba were the wheat seed varieties used in the study. Their average sphericity values were 58.94, 65.11, 63.23, 64.62, and 62.58, respectively, and they all had roughly spherical shapes. Thus, the design made use of a circular, fluted roller.

The evaluation conducted to determine the extent of mechanical seed damage that is, bruised, skin-removed, or crushed seeds showed no obvious damage to the seeds at any of the selected speeds because of the adjustable flap curvature, which reduces friction and impact between the seeds and the fluted roller.

Germination tests conducted in a lab to assess the effect of metering devices on the extent and severity of seed damage using metered seeds revealed no internal damage to the selected varieties at different speeds. The seed varieties acquired from Ethiopian Seed Enterprise's Asella branch had average percentage germination potentials of 99.00, 99.70, 99.6%, 98.8%, and 97.8%, respectively. The germination percentage did not drop for any of the selected varieties, indicating that the seeds had not been mechanically damaged by the metering devices.

Both seed drill forward speed and hoper loading level had a significant ($p < 0.05$) effect on wheat seed rate, but their combination did not have a significant ($p > 0.05$) effect. When the hopper filling level was increased from H50 (half) to H100 (full) and the operating speed was increased from 3 to 5 km/h, the seed rates had decreased. However, the combination of operating speed and hopper filling capacity had no significant impact on seed rates.

This showed that seed rates would be lower at forward speeds over 5 km/h and higher at forward speeds under 3 km/h, exceeding the recommended 125 kg/ha of wheat seeds. Nevertheless, it is clear that the effect was caused more by the variations in Hopper filling and speed levels than by their combination.

Upon analyzing the hopper fill level and seed drill operational speed, it was discovered that the forward speed of the seed drill and the hoper loading level significantly ($p < 0.05$) affected fertilizer rate, whereas the combination of the two factors had no significant ($p > 0.05$) effect on fertilizer application rate. When operating speed is increased from 3 to 5 km/h and hopper filling level is increased from H50 (half) to H100 (full), fertilizer application rates typically decrease. However, application rates were not significantly impacted by their combination.

At a forward speed of 3 km/h and a half-hopper loading capacity, 152.7 kg/ha was the highest application rate recorded. However, the lowest application rate of 146 kg/ha was attained at a speed of 5 km/h and full hopper loading capacity. This clearly showed that a forward speed exceeding 5 km/h would result in a lower application rate; conversely, a forward speed below 3 km/h would result in a higher application rate, exceeding the recommended NPS fertilizer rate of 150 kg/ha.

Overall, it is clear that forward speed and the quantity of fertilizer particles in the hopper had a major influence on the rate of application; however, the combined effects of operational speed and hopper filling level had no significant impact. However, as can be seen, variations in filling levels and speeds, rather than their combination, were the main cause of the effect.

The average theoretical field capacity of the seed drill was 0.37, 0.49, and 0.6 ha/hr at 3, 4, and 5 km/hr. At similar speed levels of 3, 4, and 5 km/h, effective field capacity was also found to be 0.31, 0.36, and 0.45 ha/hr. This shows that the theoretical and practical field capacities of the seed drill increased in line with its speed. Overall, this demonstrated that a seed drill can plant a hectare of land in 2.22 to 3.22 working hours, depending on operating speed. At the highest operating speed of 5 km/h, the field efficiency was 75.51%; at the lowest operating speed of 3 km/h, it was 80.48%. It is clear that field efficiency dropped with increasing speed.

According to Rangapara (2014), the number of drill passes increased along with the field size reduction, leading to higher time losses and lower field efficiency values. The main factor contributing to the decrease in field efficiency brought on by increasing forward speed was the theoretical time consumed, which was lower than that of the other test plots.

The average planting depth for fertilizer and seeds was 4.8 cm. This sowing depth was less than the 5 cm that agronomists advise for wheat. Nonetheless, the deviation and variability are too small and fall within an acceptable range. Averages of 377.4 plants within 1.2 m^2 area were found by the germination count after 15 days of seeding. The intended number of plants in a 1.2 m2 area was 382 plants. As a result, the seed drill reasonably satisfied the need to establish the optimal plant population for wheat seeds.

Only one person was needed to operate the tractor-drawn seed drill machine.

A single person using a tractor-drawn seed drill machine only required 3.22 to 2.22 hours per hectare, operating at a speed of 3 to 5 km/hr, whereas a single person using an animal-drawn planter required 8.33 hours per hectare to plant and fertilize a hectare of land (Ashebir, 2015). Therefore, the time required per hectare is three times shorter when using a tractor-drawn seed drill at 5 km/h than when using an animal-drawn planter.

CONCLUSION

In terms of seed and fertilizer rate, depth of seed and fertilizer placement, plant count/stand (achieving an optimum plant population), field capacity, field efficiency, labor cost, and the economics of owning and operating the machine, the developed seed drill machine performs satisfactorily, as summarized above. Above all, the developed seed drill machine successfully handled five varieties of seeds: Hidase, Danda'a, Ogolcho, Digelu, and Kekeba. Thus, it can be concluded that the majority of Ethiopian farmers are capable of using the developed seed drill in an economical, effective, and efficient manner. However, the seed drill speed should not be less than 3 km/h and not more than 5 km/h to prevent a significant and negative impact on the rate of seed and fertilizer or the recommended plant population.

Recommendations

The seed drill machine is appropriate for use on farms, according to the performance evaluation results. In order to improve the seed drill's acceptance, adaptability, and utility among farmers, the following issue must be fixed.

➢ More rows could be covered in order to boost the field capacity and efficiency of the tractor-drawn wheat seed drill.

➢ For additional design improvements, the seed drill can be tested for various cereal crops using a replaceable metering device..

➢ Consider designing, developing, and evaluating a seed drill with a plastic seed and fertilizer hopper and metering device that uses plastic rollers rather than aluminum.

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Appendix B

Laboratory Test

Table 6: Seed rate (kg/ha) calibration of wheat crop for each furrow openers per 10 revolution of ground wheel

No. of Observation	Weight of seed dropped per seed tube (gm)								
	$F.O._1$	$F.O._2$	$F.O._3$	$F.O._4$	$F.O._5$	$F.O._6$	Total seed collected (gm)	CV	Seed rate (kg/ha)
1	54.3± 0.13	53.7± 0.40	56.2± 0.71	52.8± 0.80	55.5± 0.40	55.1± 0.22	327.6	2.28	124.1
2	54.6± 0.13	54.8± 0.04	55.3± 0.80	53.4± 0.67	55.2± 0.13	56.1± 0.54	329.4	1.64	124.8
3	55.2± 0.04	55.8± 0.22	54.7± 0.27	54.2± 0.49	55.5± 0.09	56.4± 0.49	331.8	1.42	125.7

4	55.3± 0.09	55.4± 0.13	54.4± 0.31	55.1± 0.00	55.1± 0.00	55.4± 0.13	330.7	0.68	125.3
5	55.1± 0.00	55.5± 0.18	54.5± 0.27	55.1± 0.00	55.2± 0.04	55.1± 0.00	330.5	0.59	125.2
Average seed rate (kg/ha)									**125.11**

Table 7: Fertilizer rate (kg/ha) calibration from each furrow openers per 10 revolution of ground wheel

No. of Observation	Weight of seed dropped per seed tube (gm)								
	$F.O._1$	$F.O._2$	$F.O._3$	$F.O._4$	$F.O._5$	$F.O._6$	Total seed collected (gm)	CV	Seed rate (kg/ha)
1	64.8± 0.50	66.2± 0.12	66.6± 0.30	64.7± 0.54	66.1± 0.08	67.1± 0.53	395.5	1.47	149.8
2	65.7± 0.08	65.6± 0.12	66.4± 0.24	65.2± 0.30	65.8± 0.03	66.5± 0.28	395.2	0.75	149.7
3	66.1± 0.01	66.2± 0.05	66.4± 0.14	65.8± 0.12	65.8± 0.12	66.2± 0.05	396.5	0.36	150.2
4	65.8± 0.08	66±	66.1± 0.05	65.5± 0.21	66.2± 0.10	66.3± 0.14	395.9	0.44	150.0
5	66.1± 0.05	65.8± 0.08	66± 0.01	65.7± 0.12	66.1± 0.05	66.2± 0.10	395.9	0.29	150.0
Average fert. rate (kg/ha)									**149.94**

Table 8: Analysis of variance (RCBD) of effects of speed and hopper loading capacity on seed rate

Source of variation	Df	SS	MS	F value	F pr.
Hopper filling (H)	2	2.70181	1.35090	33.07	<.001
Speed (V)	2	116.18644	58.09322	1421.92	<.001
Interaction (H*V)	4	0.31972	0.07993	1.96	0.150
Residual	16	0.65369	0.04086		
Total	26	119.91171			

Table 9: Analysis of variance (RCBD) of effects of speed and hopper loading capacity on fertilizer rate

Source of variation	Df	SS	MS	F value	F pr.
Hopper filling (H)	2	2.63390	1.31695	97.87	<.001
Speed (V)	2	158.28130	79.14065	5881.09	<.001
Interaction (H*V)	4	0.22216	0.05554	4.13	0.017
Residual	16	0.21531	0.01346		
Total	26	161.38972			

Table 10: Soil moisture content and bulk density at the field condition (Dry basis)

Replication	Mass of wet soil (M_w), gm	Mass of dry soil (M_d), gm	Soil moisture content, %	Volume of core sampler, C_c	Bulk density, g/cc
1	627.6	531.4	18.10	384.85	1.40
2	659.3	561	17.52	384.85	1.46
3	644	548.7	17.37	384.85	1.42
4	636	541	17.56	384.85	1.40
5	631	537.2	17.46	384.85	1.40
Mean	639.58	543.86	17.60	384.85	1.42

Field Test Soil Moisture Content Measurement

Table 11: Seed drill performance evaluation results on (10 x 20) m^2 plot

Rep.	width, m	Length of plot, m	Time to cover 20 m,(s)	Time Loss, (s)	Operating Speed, km/h	Fuel Consumption		TFC, ha/hr	EFC, ha/hr	FE,%
						Total,(ml)	l/hr			
I	1.2	20	23	6	3.13	21.61	3.38	0.376	0.298	79.25
II	1.2	20	23	5	3.13	23.41	3.66	0.376	0.309	82.18
III	1.2	20	24	6	3.00	22.21	3.33	0.360	0.288	80.00
	Mean				3.09	22.41	3.46	0.371	0.313	80.48
I	1.2	20	19	6	3.79	22.21	4.21	0.455	0.346	76.04
II	1.2	20	16	5	4.50	24.31	5.50	0.540	0.411	76.11
III	1.2	20	18	5	4.00	22.85	4.57	0.480	0.376	78.26
	Mean		18		4.10	23.12	4.76	0.492	0.362	76.80
I	1.2	20	15	5	4.80	25.5	6.12	0.576	0.432	75.00
II	1.2	20	14	5	5.14	27.13	6.98	0.617	0.455	73.74
III	1.2	20	14	4	5.14	27.22	6.99	0.617	0.480	77.79
	Mean				5.03	26.62	6.70	0.60	0.45	75.51

Table 12: Draft measurements at different speeds

Observation No.	3.0 km/hr.		4.0 km/hr.		5.0 km/hr.	
	no-load(N)	load(N)	no-load(N)	load(N)	no-load(N)	load(N)
1	428	886	412	884	405	879
2	423	878	414	882	401	881
3	424	884	411	876	405	877
4	426	881	413	878	396	872
5	419	865	412	876	405	868
Mean	**424.00**	**878.80**	**412.40**	**879.20**	**402.40**	**875.40**
Net draft (N)	**454.80**		**466.80**		**474.00**	

Table 13: Wheel slippage measurements

Replication	Speed, km/h	Distance covered in 10 revolution		Wheel Slip,%
		Under no load, m	Under Load, m	
I	3	21.73	21.03	3.22
II		21.56	20.85	3.29
III		21.62	20.72	4.16
Mean				**3.56**
I	4	21.51	20.48	4.79
II		21.45	20.31	5.31
III		21.40	20.53	4.06
Mean				**4.72**
I	5	21.26	20.15	5.22
II		21.21	20.06	5.42
III		21.18	20.08	5.20
Mean				**5.28**

Table 14: Seed germination potential obtained at field test

Replication	Field germination count Per 1.2 m^2		
	Expected	**Counted**	**% Germinated**
1	382	378	98.95
2	382	377	98.69
3	382	375	98.16
4	382	378	98.95
5	382	379	99.21
Average	**382**	**377.4**	**98.79**