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On-Farm Evaluation of Tractor Drawn Wheat Seed Drill

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ABSTRACT

This experiment was conducted to evaluate the performance of a tractor-drawn wheat seed drill machine which can sow wheat and fertilizer at predetermined depths and row spacing. The machine performances were evaluated in terms of Seed and fertilizer rate, depth of seed placement, row spacing, plant population, field capacity, and field efficiency. Randomized complete block design with three forward speeds, three hopper loading, and three replications were used as experimental design. There were no visible or internal seeds damaged by the machine and it shows that there was no reduction in germination percentage when compared with the seed supplier recommendation. The seed and fertilizer rate was calibrated and recorded as 125 kg/ha and 150 kg/ha respectively for 20 cm row spacing. The seed drill was evaluated at speeds of 3, 4, 5 km/hr and hopper loading levels of H_{50}, H_{75}, and H_{100}. Both the operating speed and hopper loading capacity of the machine had a significant effect on seed and fertilizer rate at $p < 0.05$. The average field capacity, field efficiency, and fuel consumption at 4km/hr speed of operation were 0.43 ha/hr, 85.93%, and 3.8 l/hr respectively. 378 to 380 plant populations per 1.2 m^2 area were counted during seedling count. Depending on the results of the performance evaluation, it is concluded that the developed seed drill machine can be efficiently and economically used by the majority of farmers.

INTRODUCTION

It has been frequently claimed by agricultural experts and researchers that Ethiopia could be food self-sufficient, if the existing factors of agricultural production are well exploited. And yet, numerous factors can affect agricultural production and productivity improvement. The increased use of modern farm inputs, modernization of farming activities by using improved farm implements along with introduction of modern technologies to the sector are the major ones.

Farming system in Ethiopia is categorized as small land holdings, because of more than two-thirds of the population living in rural areas with high population density. There are 111.5 million hectares of land in Ethiopia, out of that 74.5 million hectares are suitable for agriculture, and 13.6 million hectares land is now under production (Baudron & Gerard (2013).

In Ethiopia cereal crops are the major food crops for the majority of the country's population. As well as serve as a source of income at household level and contributes in for foreign currency earnings Wheat is one of the most important cereal crops of the world and is a staple food for one third of the world's population (Hussain MI, Shah SH, 2002).

Meher Season Post-harvest Crop Production Survey shows that a total land area of about 12,486,270.87 hectares was covered by grain crops, from which a total volume of about 266,828,807.04 quintals of grains were obtained. Out of the total grain crop area, 79.88% (9,974,316.28 hectares) was covered by cereals. Wheat took up 13.33% (about 1,664,564.62 hectares) of the grain crop area. Cereals contributed 86.68% (about 231,287,970.83 quintals) of the grain production of which wheat made up 15.81% (42,192,572.23 quintals) (CSA, 2015/2016) and (Anbessie Debebe *et al.*, 2020). Ethiopia is the largest producer of wheat in sub-Saharan Africa. It ranks fourth after maize (Zea mays), sorghum (Sorghum bicolor) and teff in in terms of area coverage and ranks second in case of total production and productivity after maize. It covers about 1.80 million hectares annually (CSA, 2014), and 75.50% of the current total wheat production area is located in Bale, Arsi and Shewa highlands. In Ethiopia wheat productivity per hectare is less as compared to other wheat producing countries.

The low use of improved farm inputs (biological and mechanical), dependency on rainfall and traditional farming practices are the causes of its low production and productivity of the crops. Cognizant of this fact, extension system has been contributing efforts to promote production and productivity of wheat. Even though all the hard work made to make farmers adopt improved practices, unavailability of proper row seed drill machine made the implementation unsuccessful.

Uniform and timely establishment of optimum plant populations affects yield increment. Manual row planting practice is tedious and results in low seed placement, low spacing efficiencies and serious back ache for the farmers due to the longer hours required for careful hand metering of seeds which limits the size of the field that can be planted in rows (Kalay Khan, 2017).

To combat problems of optimum plant population establishment, Ethiopian Institute of Agricultural Research and regional agricultural engineering research centers (Melkassa, Jimma and Assella) had tried to

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develop and adapt animal drawn wheat seed drill. Other individuals including farmers had been trying to develop row planting machine to modernize wheat production in Ethiopia. Various types of animal drawn wheat row seeders were developed using different design approaches with their own advantage and limitations. Tamrat Gebiso *et al*., (2017) evaluated and verified available prototypes for wheat seed drill and recommend suitable ones for further demonstration and pre-scaling up.

Even though, wheat seed drills were designed, modified, tested and evaluated continuously by different researchers at different research centers, still there is no proven wheat seed drill that can be used under farmers' conditions.

In order to overcome these problems, tractor drawn wheat seed drill were developed and tested at AAERC for the purpose of masters' thesis project and had 0.36 ha/hr field capacity and capable of sowing 124.4 kg/ha and 149 kg/ha of wheat seed and fertilizer respectively at 4 km/hr with half hopper loading level. (Abulasan K, unpublished).

Therefore, this research project is re-initiated to enrich the data taken during the preliminary test and to have full data that was not taken due to the unavailability of budg*et al*location for successive planting seasons with the following objectives.

- To evaluate the performance of developed tractor-drawn wheat seed drill

MATERIAL AND METHODS

Descriptions of Study Area

Design, fabrication, testing, and calviration was conducted at Assella Agricultural Engineering Research Center located in the Arsi zone of Oromia Region and it has 6° 59' to 8° 49' N latitude and longitude of 38° 41' to 40° 44' E and an elevation of 2,430 meters above sea level.

Working Principles of the Machine

The operation principle of the seed drilling machine is very simple and attached to the tractor through three point linkage. Seeding can be accomplished by just pulling the seed drilling machine in well prepared and harrowed field. Since the seed and fertilizer metering is directly attached to the ground wheel shaft, the seed and fertilizer metering flute roller rotates, seeds and fertilizer are automatically dropped into the opened furrow through the seed delivery tube outlet by means of gravity.

Performance Test and Evaluation

Before actual test was carried out in the lab or field, the machine was tested to confirm the functionality of all the rotating parts, to check any malfunctioning parts and defects in the manufacturing.

The test for seed damage was conducted by rotating wheel 10 times with the seeder held (raised up) position

Figure 1: Field performance evaluation of seed drill Laboratory performance testMechanical

at fully loaded seed hopper and the discharged seeds from from each seed tube were collected and observed for any external seed damage.

Any visible damaged seeds during the calibration were separately weighed and the percentage seed damage was determined as (Rangapara J., 2014).

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

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

Uniformity of Seed Distribution

The test for seed uniformity was carried out to identify variation between furrows in seed metering devices. To assess uniformity of seeds droped from each seed tube, the machine was drawn by 25 hp tractor at predetermined speed of operation (3, 4, and 5 km/hr) and hopper loding capacity (half, three fourth and full) on 100m length track test. During the test run, sample bags were placed under each seed tube to collect the discharged seeds. Three observations were taken for each test run over 100m distance. The collected seeds in the bags for each seed metering device after each test run were weighed and compared.

Seed Germination Test

Seed germination test was conducted to check internal seed damage. To calculate the germination percentage, 100 wheat seeds discharged from seed drilling machine were sown on petri dish and counted after 10 days and percentage germination was calculated as (Rangapara J., 2014).

Figure 2: Seed germination test on petridish

Germination (%) = (N_{sg}/N_{sp}) x 100
Where, N_{sp} = Number of seed planted; N_{sg} = Number of seed germinated

Field Test
Field testing was carried out on a well prepared and harrowed test plot. Depending on the obtained parameters in laboratory test, the machine was operated at three different forward speeds 3, 4, and 5 km/hr and three different hopper filling capacity. Seed rate, seed uniformity, seed damage, time required (hr/ha), labor requirement, cost of planting, plant population, field efficiency, field effective capacity and uniformity of seed distribution as well as soil bulk density and moisture content of soil were determined during the field test.

Moisture Content of Soil
Soil samples were collected from 0 to 20 cm depth of soil surface before starting the operation to determine soil moisture content. Five soil samples were collected randomly from the test plot. The samples were placed in an oven for 24 hours at temperature of 105°C. The soil samples were weighed before and after drying. The moisture content (Db) was determined by (Rangapara J., 2014).
MC= $((M_w-M_d)/(M_d))$ x 100
Where, MC= moisture content, Mw= mass of wet soil sample, and Md = mass of dry soil sample

Bulk Density of Soil
Five soil samples were taken randomly from field plots by core sampler. The bulk density of the soil was determined from dry weight of the sample and volume of the soil sample. Bulk density of soil was calculated using the following (Rangapara J., 2014).
BDS(g/cm^3) = Md/Vs
Where, BDS= bulk density of soil; Md=mass of dry sample (g); Vs=volume of core sampler (cm^3).

Operating Speed
The operating speed of the machine was determined by recording the time required for traveling 50 m distance with the help of stopwatch.

Theoretical Field Capacity
The coverage of the implement based on 100% of time at rated operating speed and covering 100% of its rated width is known as theoretical field capacity.
TFC (ha/hr) = (Width(m) * Speed (km/hr))/(10)

Effective Field Capacity
The effective field capacity was calculated from the actual area covered by the machine, based on its total time required and its width.
Effective field capacity (ha/h) =(Actual Area covered (ha))/(time required to cover(h))

Field Efficiency
Field Efficiency is the ratio of effective field capacity to theoretical field capacity, expressed in %.

Fuel Consumption
The fuel consumption was measured by top-up method. The fuel tank was filled to its full capacity before and after the test run and amount of refilling after the end of test was the fuel consumption for the test.

Draft and Power Requirement
Draft required was measured using spring dynamometer connected to the tractor on which the machine was mounted. Another auxiliary tractor was used to pull the machine mounted tractor when the mounted implement was engaged through the dynamometer. The auxiliary tractor pulls the implement-mounted tractor with the later in neutral gear, but with the seeder in the operating position and draft was recorded in the 50 m distance. On the similar test plot, the implement was lifted off the ground and the draft was measured again. The difference between the two readings, gives the net draft of the implement as expressed by (Rangapara J., 2014).
Draft(KN) = Dl - Du
Where, D_l= draft of under loaded condition, D_U= draft of under unloaded condition
The tractor power consumption was determined by following formula:
Power(hp) = (Draft(KN) * Speed(m/s)/(75)

Wheel Slip

Wheel slip is also known as speed reduction and it occurs due to presence of soil moisture content. Wheel slippage is an important parameter which influences the machine field capacity. To determine wheel slip, a mark on the ground wheel of the machine was made to count the number of revolution of the wheel to cover 20m distance with load and without load separately. The drive wheel slip was determined by following equation (Nirala, 2011)

Wheelslip = ((A-B)/(A)) x 100

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

Row Spacing and Depth of Seed Placement

Row to row spacing was provided by fitting furrow openers at 20cm distant to the main frame with bolt and nuts before sowing operation. While seed drill was in operation, five random measurements of actual row to row spacing were recorded by using meter tape. The depth of seed and fertilizer placement was adjusted by raising or lowering the furrow opener at desired depth of seed and fertilizer placement, then the depth of seed and fertilizer placement were measured using a metering tape and graduated ruler. Randomly selected five readings were recorded for the six furrow openers from the test plot.

Plant Population and Uniformity

Plant population was determined at randomly selected spots for each experimental plot per square meter areas and by counting number of seedling emerged. Plant uniformity test was carried out by counting average number of plant in each row per meter distance and variation in between the rows was determined.

Figure 3: Plant population count

Cost of Operation

Cost analysis of annual and hourly operational costs of the tractor and seed drill machine were based on capital cost of the tractor and seed drill, interest on capital, cost of repairs and spare parts, labor cost, and depreciation. The operational cost components of the seed drill prototype and 25-hp tractor were estimated in Birr (EB) according to Wen-yuan Huang *et al* (1979). An economic life of 10 years and 850 hours per year for tractor is assumed, and the seed rill is expected to be used 425 hours per year.

Fixed Cost

Depreciation

Depreciation was a measure of the amount by which value of the machine decreased with the passage of the time. The annual depreciation was calculated as follows (Kepner *et al.*, 2005)

D = (C - S)/(L x H) (10)

Where:- D = Depreciation per hour, C = Capital investments (Birr), S = Salvage value, 10% of capital investment (Birr), L = Life of implement in hours or years, H = Annual operational hours of the seed drill

Interest

Interest was calculated based on the average investment of the machine taking into account the value of the implement in the initial and final year. The annual interest on the investment can be calculated as follows (Kepner*et al.* (2005) :-

$$I = \left(\frac{C+S}{2}\right) \times \left(\frac{i}{H}\right) \quad (11)$$

Where: - I = Interest per hour, i = interest on the investment (%) per year

Variable Cost

Repair and Maintenance Cost

The repair and maintenance cost of the machine was taken as 10% of the cost of the seed drill and tractor (Kepner*et al.*, 2005 and Kamboj *et al.*, 2012).

RM = (C x 10%)/(H) (12)

Where: - RM = Repair and maintenance cost per hour, H = Annual working hours of the seed drill

Wages of Operator

Wages was calculated based on actual wages of workers per day or hourly paid.

Total cost of Tractor Drawn Seed Drill Per Hour

The total cost of wheat sowing per hour of the tractor drawn seed drill was calculated from the summation of total fixed cost per hour and total variable cost per hour as follows.

Total Cost/h = Fixed Cost per hour + variable Cost per hour

Experimental Design

The experimental design was factorial with randomized complete block design having three replications. The three level of speed of operation and three level of hopper holding capacity were used as treatments each with three replications. The experimental design was lay as 32 with three replications and had total of 27 test runs (3x3x3 = 27).

Statistical Analysis

The data was subjected to analysis of variances following a procedure appropriate for the design of the experiment (Gomez and Gomez, 1984) and using GenStat 15th edition statistical software. The treatment means that was different at 5% levels of significance was separated using least significant difference (LSD 5%) test. The least significant difference (LSD) test was performed for the mean values of actual seed and fertilizer application rate in relation to forward speed and hopper level of filling.

RESULTS AND DISCUSSION

This study was conducted to evaluate the performance of six row wheat seed drill machine capable of sowing wheat seeds and fertilizer at predetermined rates, row spacing and depths.

Mechanical Damage Test

Table 1. indicated that the mechanical damage due to metering device were observed and it was found that there was no mechanical damage to the seeds at all the selected forward speeds, due to adjustable flap curvature to avoid impact and friction between fluted roller and seeds. The same findings were reported by Pradhan and Ghoshal (2012). Furthermore, the seed germination test was carried out and seeds germination before metering and after metering of seeds were conducted and internal damage of seeds were measured by sowing of 100 seeds in petri dish and found that no internal seed damage was observed, these mean that the observed 97 % germination potential was similar with that of predicted by seed supplier (Ethiopian seed Enterprise, Asalla branch).

Table 1: Data obtained from laboratory test of the seed drill machine

Bservations	Speed, km/h	Seed rate obtained, kg/ha	Mechanical damage, %	Germination %
1	3	127.20	0.0	97
2	4	124.18	0.0	97
3	5	121.43	0.0	97

Seed Distribution Test

Table 2 indicated that the variations in seed distribution of wheat among the rows (metering device). It was observed that the entire samples collected for the similar speed of operation and hopper loading level was nearly similar and there was slight deviation among the sample i.e. (0.28-1.48) and coefficient of variation was in range of 0.08 - 0.35.

Table 2: Mass of fertilizer fallen from each metering device per 100 m length at different speed and hopper holding capacity.

		mass of seeds from each furrow opener per 100m length, gm						
Speed	H.filling	F1	F2	F3	F4	F5	F6	CV
3	50 %	305.30 ± 0.05	305.17 ±0.01	304.33 ± 0.38	304.97 ± 0.10	305.70 ± 0.23	305.67 ± 0.21	0.17
	75 %	303.87 ± 0.21	304.97± 0.28	304.73 ± 0.11	303.90± 0.20	304.80± 0.20	303.80 ± 0.24	0.18
	100 %	305.00 ± 0.40	305.13 ± 0.46	305.00 ± 0.40	303.70 ± 0.18	303.07 ± 0.46	302.72 ± 0.62	0.35
4	50 %	297.97 ± 0.03	298.23± 0.10	297.97 ± 0.03	298.37 ± 0.15	297.73 ± 0.13	297.93 ± 0.04	0.08
	75 %	296.10 ± 0.24	296.27 ± 0.16	296.60 ± 0.02	297.00 ± 0.16	296.70 ± 0.03	297.20 ± 0.25	0.14
	100 %	295.13 ± 0.25	296.43 ± 0.33	295.77 ± 0.03	295.87 ± 0.08	295.30 ± 0.17	295.63 ± 0.03	0.16
5	50 %	293.63 ± 0.01	292.87± 0.33	293.63 ± 0.01	293.23 ± 0.17	294.47 ± 0.38	293.83 ± 0.10	0.19
	75 %	292.20 ± 0.17	292.53 ± 0.03	292.17 ± 0.20	292.90 ± 0.14	292.23 ± 0.16	293.53 ± 0.42	0.18
	100 %	291.70± 0.17	292.23 ± 0.06	292.40 ± 0.14	292.17 ± 0.03	291.73 ± 0.16	292.33± 0.11	0.10

Effects of Seed Drill Forward Speed on Seed Rate

The analysis of variance (ANOVA) shows that the machine operational speed and hoper filling level had significant effect ($p < 0.05$) on wheat seed rate, where as the interaction of hoper loading level and machine forward speed had no significant effect ($p > 0.05$) on wheat seed rate. Table 3 shows the effect of forward speed, hopper filling level, and the combined effect of forward speed and level of hopper loading on wheat seed rate. Figure 4 shows the relationship between machine forward speed and seed rate.

Increasing forward speed from 3 to 5 km/hr as well as increasing hopper loading level from H_{50} (half) to H_{100} (full) had decreased the seed rates. Nonetheless, the

Table 3: Effects of seed drill operating speed and hopper filling level on seed rate

Parameter	Source of variation			Measure of differences	
	Speed level			LSD (5%)	SE(M)
Seed rate (Kg/ha)	V_3	V_4	V_5	0.20	0.06
	127.20^a	124.18^b	121.43^c		
	Hopper filling level				
	H_{50}	H_{75}	H_{100}	0.20	0.06
	124.70^c	124.21^b	123.90^a		

	Interaction(V*H)					
	Speed level	H_{50}	H_{75}	H_{100}	0.33	0.11
	V_3	127.59^{a}	127.21^{b}	126.81^{c}		
	V_4	124.48^{d}	124.19^{de}	123.85^{fg}		
	V_5	122.02^{h}	121.24^{ij}	121.04^{ik}		

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

forward speed and hopper loading level combination had no significant effect on wheat seed rates. Maximum seed rate of 127.59 kg/ha were observed at forward speed of 3 km/hr and half hopper filling level. Whereas the minimum seed rate of 121.04kg/ha were obtained at 5 km/hr and full hopper filling capacity. This clearly shows that speeds higher than 5 km/hr would results in less seed rate, in contrast speeds less than 3 km/hr would results in higher seed rate, which can result beyond the recommended 125 kg/ha of wheat seeds ((informal communication with experts).

In general, it can be seen from Table 3. The level of seed and hopper filling had significant effect on seed rate but their combination had not significant effect on seed rate. Nonetheless, the effect was dominantly due to disparity in hoper filling level and speeds than their combination.

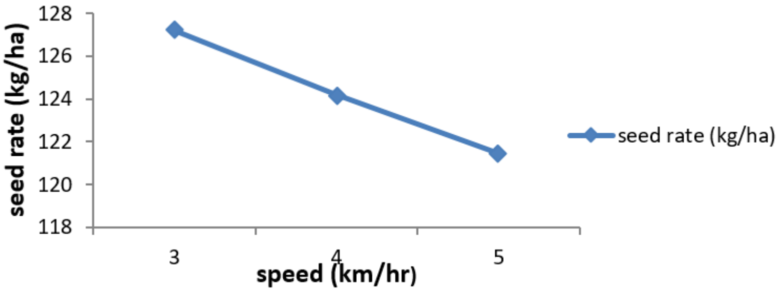

Figure 4: Effects of seed drill forward speed on wheat seed rate

Effects of Seed Drill Operating Speed on Fertilizer Rate

The analysis of variance (ANOVA) revealed that the seed drill operating speed and level of hoper filling had significant effect ($p < 0.05$) on fertilizer rate, where as the combination of hoper filling level and seed drill operating speed had no significant effect ($p > 0.05$) on fertilizer application rate. Table 4 shows the effect of speed, hopper loading level, and their combined effect on fertilizer rate. Figure 5 shows the relation between seed drill operating speed and fertilizer application rate.

Increasing forward speed from 3 to 5 km/hr as well as increasing hopper loading level from H_{50} (half) to H_{100} (full) tends to decrease fertilizers rates. Nevertheless, their combination had no significant effect on application rates. The maximum application rate of 152.60 kg/ha was observed at 3 km/hr speed and half hopper filling level . Whereas minimum application rate of 146.05 kg/ha were observed at of 5 km/hr speed and full hopper filling level. It can be seen that speeds greater than 5 km/hr would results in less application rate, in contrast speeds less than 3 km/hr would results in higher application rate, which exceeds the recommended 150 kg/ha of NPS-fertilizer rate ((informal communication with experts).

In general, it can be seen from Table 4 the level of

Table 4: Seed drill forward speed and hopper loading level Effects on fertilizer rate

Parameter	**Source of variation**				**Measure of differences**	
	Speed level				**LSD (5%)**	**SE(M)**
	V_3	V_4	V_5		0.15	0.05
	152.27^{a}	148.40^{b}	146.38^{c}			
Fertilizer rate (Kg/ha)	**Hopper filling level**					
	H_{50}	H_{75}	H_{100}		0.15	0.05
	149.47^{c}	148.93^{b}	148.65^{a}			
	Interaction(V*H)					
	Speed level	H_{50}	H_{75}	H_{100}	0.27	0.09
	V_3	152.60^{a}	152.17^{d}	152.05^{d}		
	V_4	149.02^{b}	148.33^{ef}	147.85^{gh}		
	V_5	146.81^{c}	146.30^{ij}	146.05^{ik}		

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

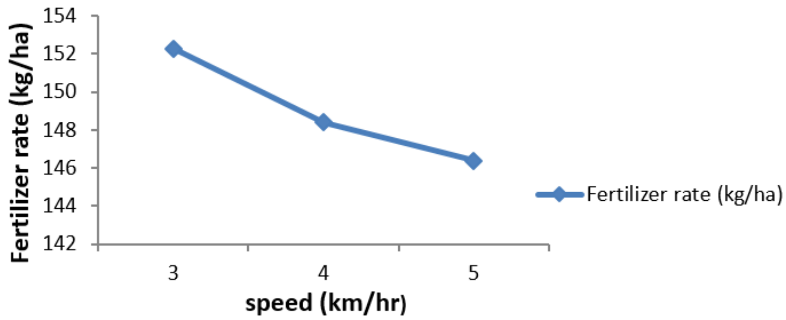

Figure 5: Effects of seed drill speed on fertilizer rate

fertilizers particles in the hopper and forward speed had significant effect on application rate but the combined effect of speed of operation and hopper loading level had no significant effect on application rate. However, the effect was dominantly due to variation in speeds and hoper level of filling than their combination.

Moisture Content of Soil

Five soil samples were randomly taken at different places in experimental plots at 0 to 20 cm depth from the surface of soil. From table 5, the average moisture content at 20 cm depth was found 17.67 % on dry basis.

Bulk Density of Soil

The soil bulk density was measured by core cutter method with having size of core cutter having 7 cm inner diameter and 12 cm height. Five soil samples were taken at the depth level of 0 to 20cm before sowing operation. The soil samples were weighed before placing into an oven for 24 hours at 105^0 C and after drying the weight of sample was measured again. The average bulk density was found to be 1.40 g/cm3 as shown in Table.5. Table5. Soil moisture content and bulk density at the field condition (Dry basis).

Table 5: Soil moisture content and bulk density at the field condition (Dry basis)

Replication	Soil moisture content, %	Bulk density, g/cc
1	18.04	1.39
2	17.86	1.44
3	20.86	1.37
4	21.75	1.41
5	19.86	1.39
Mean	**19.67**	**1.40**

Operating Speed

The operational speed was conducted on the speed limit at 3 km/h, 4 km/h and 5 km/h (Table 6). The stopwatch instrument was used to measure operating speed. The optimum operational speed of tractor drawn seed drill for sowing seeds was found to be 4 km/h, which results better seed and fertilizer rate for a distance of 50m.

Theoretical and Effective Field Capacity

As shown in the Table 6, the mean theoretical field capacity of the machine at 3, 4, 5 km/hr were 0.37, 0.50,

Table 6: Seed drill performance evaluation results on (10 x 50) m^2 plot

Rep.	Width, m	Length of plot, m	Time to cover 50 m,(s)	Time Loss, (s)	Operating Speed, km/h	Fuel Consumption		TFC, ha/hr	EFC, ha/hr	FE,%	Wheel slip(%)	Draft (N)
						Total,(ml)	l/hr					
I	1.2	50	58	6	3.10	46.8	2.6	0.37	0.34	90.63	2.52	
II	1.2	50	57	9	3.16	45.9	2.5	0.38	0.33	86.36	2.62	
III	1.2	50	60	7	3.00	47.6	2.6	0.36	0.32	89.55	2.61	
	Mean	**50**	**58**	**7**	**3.09**	**46.8**	**2.6**	**0.37**	**0.33**	**88.82**	**2.58**	**454.80**
I	1.2	50	42	7	4.29	51.2	3.8	0.51	0.44	85.71	3.77	
II	1.2	50	45	6	4.00	53.4	3.8	0.48	0.42	88.24	5.17	
III	1.2	50	42	8	4.29	52.6	3.8	0.51	0.43	84.00	4.88	
	Mean	**50**	**43**	**7**	**4.19**	**52.4**	**3.8**	**0.50**	**0.43**	**85.93**	**4.61**	**466.80**
I	1.2	50	37	8	4.86	56.1	4.5	0.58	0.48	82.22	4.87	
II	1.2	50	35	7	5.14	55.8	4.8	0.62	0.51	83.33	5.45	
III	1.2	50	35	9	5.14	55.2	4.5	0.62	0.49	79.55	5.84	
	Mean	**50**	**35.67**	**8.00**	**5.05**	**55.7**	**4.6**	**0.61**	**0.50**	**81.69**	**5.39**	**474.00**

and 0.61ha/hr, respectively. The effective field capacity the machine at speed level of 3, 4, 5 km/hr were found to be 0.33, 0.43, and 0.50 ha/hr respectively (table 6). This indicated that both effective field capacity and theoretical field capacity of the machine increased with increase in operating speed as shown in figure 3.3. In general, this indicated that the seed drill can sow a hectare of land in 2.0 to 3.03 working hours based on the forward speed.

Field Efficiency

The mean values of field efficiency obtained were presented in table 6. The lower field efficiency occurred at 5 km/hr was 81.69% and the higher field efficiency was obtained at 3 km/hr was 88.82%. It can be observed that from the figure 6, field efficiency was decreased as speed increases. According to the finding of Rangapara J. (2014), as the size of the field was decreased; number of passes of the machine increased too, which results in increase in time losses and gave lower values of field efficiency.

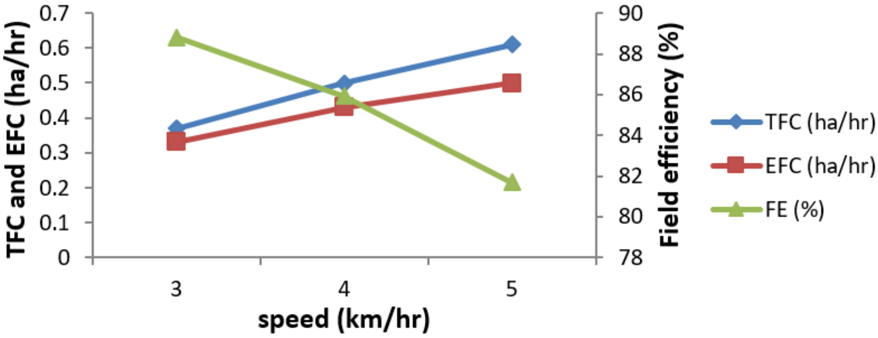

Figure 6: Effects of seed drill forward speed on theoretical, effective field capacity and field efficiency

Fuel Consumption

The results obtained for different forward speed indicated that mean fuel consumption was increased with increase in speed (Table 6). During test run, mean fuel consumption was measured as 2.6, 3.8and 4.6 l/h at the speed of 3, 4 and 5 km/hr, respectively.

Draft and Power Requirement

Spring dynamometer was used to measure the draft required to operate the seed drill. The mean values of the net draft were measured as 454.80, 466.80 and 474.00 N at the speeds of 3, 4 and 5 km/hr, respectively (Table 6). The higher draft was measured as 474 at 5 km/hr and less 454.80 N at 3 km/hr forward speeds. Besides that, power required to operate the seed drill was determined based on operational speed and the draft required to operate the seed drill. The Power requirement was found to be 3.79, 5.2, and 6.58 Watt at 3, 4, and 5 km/hr respectively. The measured results of both draft and power requirements are indicated in Fig.7. It can be seen from the figure that both draft and power required to operate the seed drill was increased with increase in the forward speed.

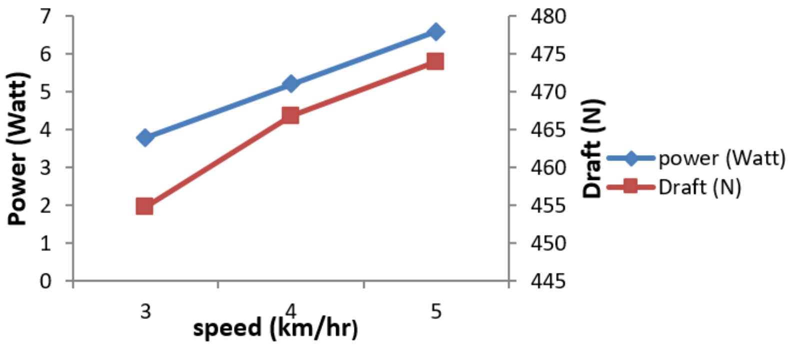

Figure 7: Effect of speed on draft and power requirement

Wheel Slip

The wheel slippage of tractor drawn wheat seed drill was determined by using the method mentioned earlier and as shown in Table 6, less wheels slip of 2.58% and higher wheel slippage of 5.39% was recorded at speed of 3 km/h and 5 km/h, respectively. It can be seen that the wheel skid was slightly increased with increase in operating speed.

Plant Populations and Uniformity

The plant stand count was conducted in the experimental plot after sowing Ogolcho wheat variety having germination potential of 97% (Ethiopian seed enterprise, Asalla branch). Number of seedling germinated per 1.2 m^2 area after fifteen days was counted and presented in table 7. The seed rate indicated that metering mechanism was properly metering the seeds without damage. However, there was some disparity of seeds emergence at the experimental field as compared to the recommended seed emergence, these variations might be due to environmental factors.

Table 7: Seed germination potential obtained at field test

Replication	Field germination count Per 1.2 m^2		
	Expected	Counted	% Germinated
1	392	379	96.68
2	392	380	96.94
3	392	379	96.68
4	392	378	96.43
5	392	379	96.68
Average	**392**	**379**	**96.68**

Economical Evaluation

Tractor drawn seed drill machine required only a single operator to drive tractor. The time required to plant and fertilizes a hectare of land using animal drawn planter, with one person, was 8.33 hours-ha-1 (Ashebir, 2015), while a single person, using the tractor drawn seed drill machine, required only 3.03 to 2.0 hours-ha-1 at forward speed of 3 to 5 km/hr respectively to do the similar operation. Thus, it is clearly indicated that the time required per hectare land is three times less than operating with animal drawn seed drill when tractor drawn seed drill is used at 5 km/hr.

CONCLUSIONS

From the results obtained, it can be noted that the wheat seed drill machine performance in terms of seed and fertilizer rate, depth of seed and fertilizer placement, plant population, field capacity, field efficiency, labour cost and cost of owning and operating the machine is acceptable. Thus, it can be concluded that the developed seed drill can be efficiently and economically used by the majority of Ethiopian farmers. However, the speed of operation of the seed drill should not be less than 3 km/hr and not exceed 5 km/hr in order to have optimum plant population. From this research finding, it can be concluded that 4 km/hr operating speed and half hopper filling level was the point where seed drill performs better in terms of optimum seed and fertilizer rate of application.

RECOMMENDATIONS

In general, the performance evaluations showed that the machine can be used successfully on sowing operations. However, the following issue must be addressed to make the seed drill more adaptable, popular, and usable among the farmers.

- •.Number of rows for developed tractor-drawn wheat seed drill might be increased to improve field capacity and field efficiency.

The seed drill may be tested for different cereal crops with a replaceable metering device for further design refinements and consider using plastic rollers, instead of aluminum, as metering devices and plastic seed and fertilizer hopper in the seed drill.

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