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Full Length Research

Performance Evaluation of Walking Tractor Drawn Wheat Planter

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Wheat is one of the leading food crops in Ethiopia. The small power operated walking tractors are being used by farmers for various farm operations. The developed walking tractor drawn wheat planter was tested in the laboratory and field. The seed rate was calibrated and observed that 112 kg/ha with a 4.5 mm cups depth adjustment which is laying in the acceptable range of 100 to 125 kg/ha. There was no visible damage observed. The preliminary test conducted at speed of 1.4, 2 and 2.5 km/h speed shows good seed rate but 2.5 km/h speed gave better operation result than other operating speeds. 350 to 372 plants population per 1.2 m^2 area were observed during field germination count. The theoretical field capacity, effective field capacity and field efficiency of the machine were 0.30 ha/hr., 0.23 ha/hr. and 77.91 % respectively. The performance of walking tractor drawn six-row wheat drill was good for working in the well-prepared seedbed for sowing*.*

Keywords- Planter, Seed Rate, walking Tractor, Wheat

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INTRODUCTION

Agricultural mechanization has a significant contribution to agricultural development and its purposes are increasing land and labor efficiency by reducing the difficulty in farming operation, bringing more lands under cultivation, save energy and resources.

Ethiopia framing system is categorized as small land holdings, due to high population density with more than two-thirds of the population residing in rural areas. There are 111.5 million hectares of land in Ethiopia, 74.5 million hectares of which is suitable for agriculture, and 13.6 million hectares of which is currently under production. Farmers produce cereal crops like wheat, barley, and rice (CIMMYT, 2014).

In Ethiopia, wheat is one of the major food crops. It is the second important cereal crop with annual production of about 3.43 million tons cultivated on an area of 1.63 million hectares (CSA, 2013). Based on CSA (2013) data, wheat occupied about 17% of the total cereal area with an average national yield of 2.11 t/ ha. This is low compared to the world average of 4 t/ha (FAO, 2009). The demand for wheat has been increasing due to growing population, urbanization and the expansion of food processing industries in the country.

The relatively slow growth in mean national yield for bread wheat (*Triticum aestivum* L.*)* from 1.46 t/ha in 2004/2005 CSA (2005) to 2.01 t/ha CSA (2011) is due to several constraining factors, such as poor crop management that include the prevalence of poor weed control, aggravated by the limited availability of herbicides in the market and its improper use, depleted soil fertility and lack of small-scale agricultural machineries like seeder.

Walking tractors are sources of power designed to perform most field operations. Due to the size of such tractors, they become an economic alternative to small farming. In addition, walking tractors are much more productive than animal traction and they require less time for attendance and preparation, giving the individual farmer more independence and contact with modern technology (Bill, 1999).

The developed walking tractor drawn wheat planter could have components of cup feed metering mechanism, seed hopper, ground wheel, furrow opener, soil covering device and walking tractor itself for a power source. The planter could get the power for a ground wheel for picking and delivering the wheat seeds. Theoretically walking tractor drawn planter could maintain the seed uniformity between rows.

A uniform distribution of seed with 20 cm spacing along the row planting is desirable. The cup metering mechanism required to hold the seed in each cup should be between 12 to 15 seeds based on the physical property carried out to maintain the seed rate of 100 to 125 kg/ha and the required plant population should be 377 plants /m^2. The developed planter could place the seed 3 to 5 cm below the ground surface.

MATERIALS AND METHODS

Study Area

The study site was located 17 km away south of Adama at Melkassa Agricultural Research Center (MARC). It's found at an elevation of 1560 m above sea level with point locations of $8^0$24' N latitude and $39^0$21' E longitude. The average annual rainfall in the area is 768 mm, which is erratic and uneven in distribution. The site has a mean maximum temperature of 30.5^{0}C and mean minimum temperature of 12. 6^{0}C.Clay loam and sandy loam soil textures are the dominant soils of the area. Testing of the prototype was carried out at Melkassa Agricultural Research Center (MARC) trial field.

The planter (Figure 1) consists of cup feed metering mechanism, seed hopper, furrow opener, round wheel, and shafts. The planter was designed to performs the following functions: (a) to carry the seeds, (b) to open furrow to the uniform depth, (c) to meter the seeds, (d) to place the seed in furrows in an acceptable pattern, and (e) to cover the seeds and compact the soil around the seed.

A. F Ground drive wheel
B. Furrow openers and boot
C. Drawbar
D. Furrow opener frame
E. Seed outlet orifice
F. wheel shaft
G. Frame
H. Hopper
I. Cup type metering mechanism
J. Seed metering Shaft
K. Chain and Sprocket
L. Spoke

Performance Evaluation of Planter (Figure 2)

The Developed walking tractor drawn wheat planter was tested in the laboratory and Field.

Laboratory Test

This test encompassed the calibration of the seeder and seed germination test. It was done to determine the seed dropping rate obtainable at different settings and the variation among furrow openers when the planter was stationary.

Seed Damage Test (SD)

This test was carried out to determine the percentage of seed damage during calibration. For each test, one kilogram of seed from each bag was taken and was labeled with test number and opener. The seeds which were used for metering was tested before and after the test to ensure its invisible (germination) damage and the samples of the seed obtained after passing through the metering was tested to ensure its visible damage. Then, Count the number of seeds with visible damage. The percentage of damaged seed was calculated using (Rangapara, 2014).

$$SD = \frac{\text{weight of damaged seed}}{\text{total weight of seeds collected}} \times 100 \quad (1)$$

Uniformity of Seeding (US)

This test was carried out to determine seed uniformity among furrow openers during drilling. The test was carried out in the laboratory by using 10 m long grease polishing (sticky) mat. A sticky layer of grease was applied to the belt to facilitate the proper embedding of seeds without any displacement. The seed tube was kept as close to the mat layer as possible. The drill was operated and the number of seeds dropped for each meter of mat layer length for recommended seed rate was observed. The steps were repeated at least three times and an average of readings was taken.

Seed Emergence Test (SE)

This test was conducted to find visible damage to seed if any by metering mechanism. The seeds before and after metering mechanism test carried out for germination. Take the Petri dish and it covers with blotting paper and

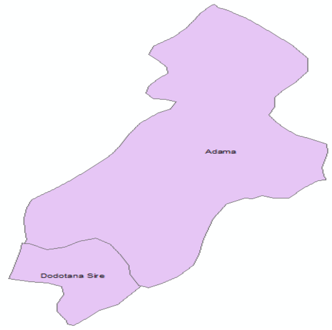

Figure 1. Map of study site

Description of walking Tractor Drawn planter

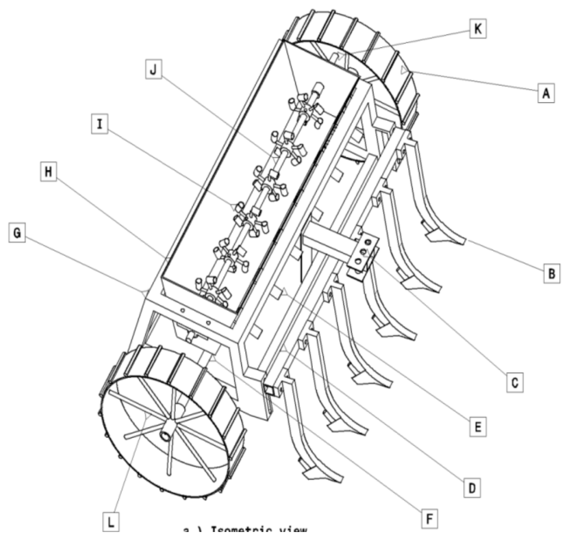

Figure 2. Planter parts representation

adds some amount of water for wetness. Take the 100 grains from seed metering mechanism and place on wetted blotting paper. After 7 days seed was germinated. The germinated seed was counted and percentage of seed germination was found out. The seed emergence was calculated using (Rangapara, 2014).

$$SE = \frac{\text{number of seeds germinated}}{\text{number of seeds planted}} \times 100 \quad (2)$$

Field Test

The planter was attached to the walking tractor. Three different operating speeds were found out at different gear and throttle position. The 1.4 km/h, 2 km/h, and 2.5 km/h speed were selected for sowing operation and effect of different operating speed on seed rate, seed uniformity and seed damage was observed. The best results' giving operating speed was chosen for sowing wheat varieties.

Experimental Design

The Experiments were conducted in the field with Kekeba wheat variety (K) and three forward speed of walking tractor of 1.4 km/h, 2 km/h and 2.5 km/h with forming three treatments.(see Figure 3)

Each treatment replicated three times with using Randomized Complete Block Design (RCBD) as shown in Fig 1.3.

The well prepared experimental field was divided into 9 plots each having an area of 220 m^2 (i.e. 10 m x 22 m plot size). Various adjustments in the machine were done to get required seed depth and plant to plant distance before testing. After preparing the field plot, the fertilizer

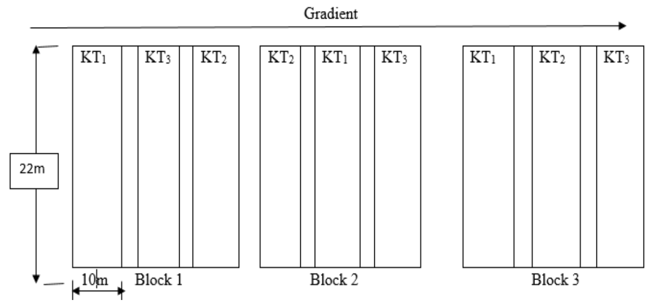

Figure 3. RCBD plot size sample representation

was broadcasted on the plot as per the recommended rate of 100kg/ha. The walking tractor drawn planter was adjusted at 1.4 km/h, 2 km/h, and 2.5 km/h throttle position and sowing operation were carried out for each randomly selected plot samples by taking a performance evaluation data.

Planter Performance Parameters

Operating Speed

The operating speed of planter was carried out by observing the time required for traveling 20 m distance with the help of stopwatch along with the longest direction.

Fuel Consumption

The fuel consumption was measured as per the standard method by observing the fuel required for traveling 20 m long distance using a known volume cylinder apparatus directly attached to the fuel tank and noted the consumption.

Theoretical Field Capacity (TFC)

It is the rate of field coverage of the implement, based on 100 percent of the time at the rated speed and covering 100 percent of its rated width in ha/hr.

$$\text{TFC} = \frac{\text{Theoretical width (m)} \times \text{speed (km/h)}}{10} \quad (3)$$

Effective Field Capacity (EFC)

It is the actual area covered by the implement, based on its total time consumed and its width. Rangapara (2014) expressed the relation of effective field capacity in ha/hr was:

$$\text{EFC} = \frac{\text{area covered ,ha}}{\text{time taken to cover the test area,h}} \quad (4)$$

Field Efficiency

The field efficiency is the ratio of the effective field capacity to the theoretical field capacity, usually measured in terms of percentage (Rangapara, 2014).

$$\text{Field efficiency (\%)} = \frac{\text{EFC}}{\text{TFC}} \times 100 \quad (5)$$

Wheel Slip

The wheel slip was calculated by recording a total number of revolutions at no load and the total number of revolutions at load. Wheel slip represents a loss of forwarding motion of the implement and it represents the loss of power. Wheel slip for any given load is determined by the expression of (Rangapara, 2014).

Draft and Power Requirement

a) The tractor (another power source) was used for pulling the walking tractor.
b) The spring type dynamometer was attached in between walking tractor and tractor.
c) Pull the walking tractor with the help of a tractor and note the readings (unloaded condition).
d) The planter was attached to the walking tractor and pulls the walking tractor with the help of a tractor. (Loaded condition).
e) Note down the readings and repeat the procedure five times
f) Draft required to pull planter can be calculated by (Rangapara, 2014).

Draft requirement (kgf) = D_L- D_U

The power requirement (HP) can be calculated by (Rangapara, 2014).

$$HP = \frac{\text{draft(kgf) x speed(m/s)}}{75} \quad (6)$$

RESULTS AND DISCUSSION

Performance Evaluation of Planter

Performance evaluation of wheat planter was carried out by conducting both laboratory test and field test at Melkassa Agricultural Research Center. Walking tractor was used to pull the wheat planter using some technical specifications of Dongfeng power tiller.

Laboratory test

Planter Calibration

The planter was tested in the laboratory for mechanical damage to seed during metering and for seed rate. The width of walking tractor drawn wheat seeder was 1.2 m. The diameter of the ground wheel diameter was 50 cm.

Circumference of ground wheel (∏ x D) =3.14 x 0.5=1.57 m. Let, the length of a strip of the plot was 100 m. The ground wheel was revolved 63 times for 100 m length i.e. X = 100/ (π × 0.2) = 63revolution for a 120m^2 (i.e. 1.2 m x 100m). The 63 revolution was given to the wheel and the seeds from all the furrow openers were collected separately. All the collected seeds were weighed separately. The total weight of the seeds collected from six furrow openers was 1.34 kg. In one ha there are 83.33 turnings (i.e. 100m/1.2m = 83.33 turnings). Therefore, 83.33*1.34kg=112kg wheat was required for one hectare. The process was repeated by suitable adjusting the speed on the 2WT till we get desired seed rate recommended for a wheat variety undersowing.

Three replications were carried out for calibrating the drill in the laboratory. The available cup metering mechanisms depth of 4mm, 4.5mm, and 5mm were used for the study. Looking to the observed values of seed size and cup size of cup metering mechanism, cup depth of 4.5mm was selected for calibration of the developed planter for wheat. Data revealed that with cup metering depth of 4.5mm gave nearest values of seed rate in the range of 100.13kg/ha to 112.04 kg/ha. The obtained seed rate result was laid on the recommended range of wheat seed rate of 100kg/ha to 125kg/ha (data gathered from the informal communication of research expert). Average value of 106.08 kg/ha was obtained which is nearest to the minimum recommended seed rate of 100kg/ha of wheat.

The average seed rate for 1.4 km/hr, 2 km/hr, and 2 km/hr speed of operation from the calibration were observed as 100.13 kg/ha, 105.58 kg/ha and 112.04 kg/ha respectively as shown in table 1.

The recommended seed rate of wheat variety ranges from 100kg/ha up to 125kg/ha. Therefore, the calibrated seed rate of developed tractor drawn wheat seeder was lies in the recommended range.

Uniformity Test

Seed uniformity test was conducted as per the method is given in the above section. The average number of seeds fallen in each row per meter distance were counted as shown in table 2. The variation in seed rate from the six-row metering was lower.

Mechanical damage

The Mechanical damage test was carried out as per the method in the section listed above and it was observed that there was no visible damage to all types of cup rows test in a laboratory test as shown in table 3. This result occurred due to cup design based on the physical property. The similar findings were reported by Pradhan and Ghoshal (2012).

Seed Emergence Test

The seed emergence test was conducted and results observed germination of wheat before metering and after metering of selected variables were carried out. The variation in germination values was within 1% before and after metering which is within an acceptable limit. The similar results were reported by Senger et al. (2010).

For a 100m length of trip distance, the planter dropped a 1340 gm of seeds for the 120 m^2 areas. Then calculate the rate of seed sown for a 1m distance i.e. for 1.2 m^2 area. The result became 13.4 gm. The average value of a thousand grain mass was 35.5 gm (see table 4 & Figure 4, 5). From this data obtained the number seed fallen in a 1.2 m^2 area would be about 377 seed.

Table 4 Evaluated the germination result of the seed planted by different speed operation conducted at the experimental field site. After testing the planter, germination percent was found as 97.8%, 96.7% and 95.2 % at speed 1.40, 2.0 and 2.5 km/h, respectively.

Effect of Seed Rate on walking tractor Speed

The planter was attached to the 15hp Dongfeng walking

Table 1. Seed rate data obtained

speed, km/h	Rep.No.	weight of seed from each furrow opener per 14 revolution, gm						Total Seed Collected, gm	Seed Rate, kg/ha
		1	2	3	4	5	6		
1.4	1	44.4	43.9	44.8	44.2	44.2	43.9	264.41	99.40
	2	44.9	44.07	44.9	43.6	44.2	44.3	265.97	99.98
	3	44.5	44.9	44.7	44.9	44.8	44.9	268.7	101.02
	Average	44.6	44.29	44.8	44.1	44.4	44.1	266.36	100.13
2	1	46.8	47.1	46.8	47.2	45.7	45.9	279.5	105.07
	2	45.9	46.8	45.5	47.9	47.8	47.8	281.7	105.90
	3	47.8	48.5	45.9	45.3	46.8	47.1	281.4	105.78
	Average	46.8	47.46	46.06	46.8	46.7	46.9	280.86	105.58
2.5	1	49.4	50.9	48.9	49.2	50.1	48.8	297.3	111.76
	2	48.5	50.1	49.1	49.2	49.8	50.1	296.8	111.55
	3	49.9	51.1	49.8	48.9	49.1	51.2	300	112.78
	Average	49.2	50.7	49.26	49.1	49.6	50.0	298.03	112.04

Table 2. Seed uniformity data obtained

Sr.No	Furrow Rows	Variety	Seed Rate (kg/ha)	No. Seeds Fallen Per Meter Distance
1	Row1	Kekeba	118.8	66
2	Row2		109.1	61
3	Row3		107.5	64
4	Row4		111.1	63
5	Row5		112.8	65
6	Row6		102.5	62

Table 3. Mechanical damage tests

Sr.no	Crop variety	Weight of broken seeds, gm	Total weight of sample, gm	Damaged seeds %
1	Kekeba	0.09	1000	0.009%
2	Kekeba	0.10	1000	0.01%
3	Kekeba	0.05	1000	0.005
4	Kekeba	0.08	1000	1.008
5	Kekeba	0.12	1000	0.012
Average		0.088	10000	0.088%
Seed collected in 20 wheel revolutions				

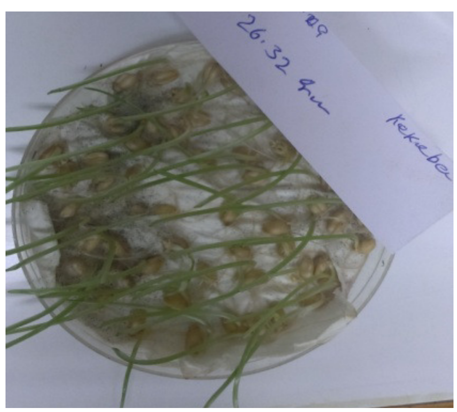

Figure 4. Laboratory germination test

tractors. The 1.4 km/h, 2 km/h, and 2.5 km/h forward speed were selected for sowing operation and its effect on different operating speed on seed rate, seed uniformity, and seed damage was observed. (see Figure 6)

At 1.4 km/h speed was observed that relatively less

Table 4. Germination data obtained

Field Germination Count Per 1.2 m^2				
Sr.NO	Speed, km/h	Recommended	Count	% Germinated
1	1.4	377	369	97.8
2	2	377	364	96.7
3	2.5	377	358	95.2

Figure 5. Field germination view

Figure 6. Effect of different operating speed on seed rate

rotational speed of the cups due to lower gear speed. These resulted cups were not dropping all the picking seeds into the outlet. Some of the seeds dropped back to the hopper. At this speed operation the seed was drilled in a row continuously and lower seed rate was observed but it was in the recommended range of seed rate. At 2 km/h speed was gives better results than the 1.4 km/h speed, but in this speed, seed rate was not reached to the average recommended seed rate. It gives less seed rate than average seed rate. The 2.5 km/h speed was giving an average seed rate. In 2.5 km/h operating speed seed rate, as well as seed spacing, was properly maintained as per requirement as observed in a laboratory test. Therefore 2.5 km/h speed was selected for sowing operation and give better results than the other operating speed. The recommended rate of wheat sowing in Ethiopia is 100 kg/ha to 125kg/ha

Effect of Seed Delivery between Rows

Table 5 indicate the variation in seed rate of wheat among furrow openers. It was observed that the entire samples collected for the samples taken were nearly the same as shown in table 5.

Field Test

The field calibration of walking tractor drawn wheat

Table 5. Seed rate (kg/ha) data for each row

Sample	F.O-1 (gm)	F.O-2 (gm)	F.O-3 (gm)	F.O-4 (gm)	F.O-5 (gm)	F.O-6 (gm)	Mean	SD	Seed Rate(kg/ha)
I	45.11	48.98	41.21	42.5	45.01	43.89	44.45	2.68	111.12
II	45.5	47.5	44.01	40.5	39.6	43.9	43.5	2.99	108.75
III	38.98	47.99	44.92	45.9	42.85	45.18	44.3	3.09	110.75
IV	49.56	43.93	45.25	45.98	48.11	44.98	46.3	2.12	115.75
V	45.11	48.6	42.1	45.9	42.12	44.01	44.64	2.26	111.6
Average seed rate, kg/ha									111.59

F.O-1: furrow opener of row 1, F.O-2: furrow opener of row 2, F.O-3: furrow opener of row 3, F.O-4: furrow opener of row 4,F.O-5: furrow opener of row 5, F.O-6: furrow opener of row 6

Figure 7. Walking tractor drawn planter

Table 6. Mean Performance Evaluation data

Sr. No.	Parameters	Operating speed, km/hr 1.4km/hr	2km/hr	2.5km/hr
1	Fuel consumption, l/hr	1.42	1.66	1.53
2	Draft requirement, kg	61	67	69
3	Power Requirement, hp	2.93	6.43	8.28
4	Wheel slip,%	4.94	6.19	8.67
5	Theoretical field capacity, ha/hr	0.17	0.24	0.3
6	Effective field capacity, ha/hr	0.14	0.19	0.23
7	Field efficiency, %	81.61	78.43	77.91

seeder was carried out at the experimental field of Melkassa Agricultural Research Center. Three plots of size 10m x 22m were selected for field testing.

Performance Evaluation of Planter

Field performance tests were carried out to obtain actual data on the overall performance of the drill. The field test was done on the experimental farm of Melkassa Agricultural Research Center (MARC). The performance of the walking tractor drawn planter in terms of planter agricultural machine parameters was assessed at different forwards speeds of 1.4, 2.0 and 2.5 km/h. Since a variety of seed has no effect on the planter, therefore, seed variety was not considered during this test. During field performance test, the parameters determined was theoretical field capacity, effective field capacity, field efficiency, wheel slippage and power requirement of walking tractor operated planter with three replications of each. (See Figure 7)

The theoretical field capacities were observed that 0.17, 0.24 and 0.30 ha/h at operating speeds of 1.4, 2.0, and 2.5 km/hr respectively. The average effective field capacities were observed that 0.13, 0.19 and 0.230 ha/h at operating speeds of 1.4, 2.0, and 2.5 km/hr respectively. The field efficiency was observed that 81.6 %, 79.4 % and 77.9 % at an operating speed of 1.4, 2.0, and 2.5 km/hr respectively as shown in table 6.

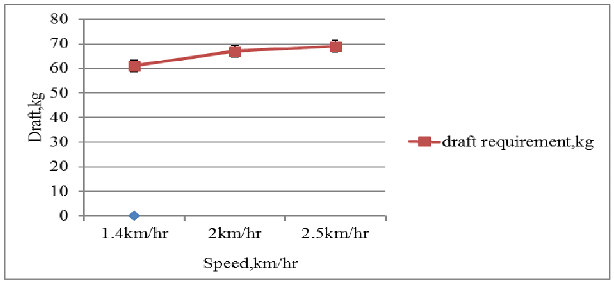

Figure 8. Effect of forwarding speed on draft

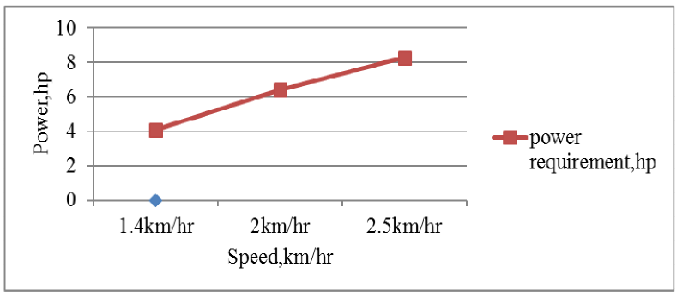

Figure 9. Effect of speed on power requirement

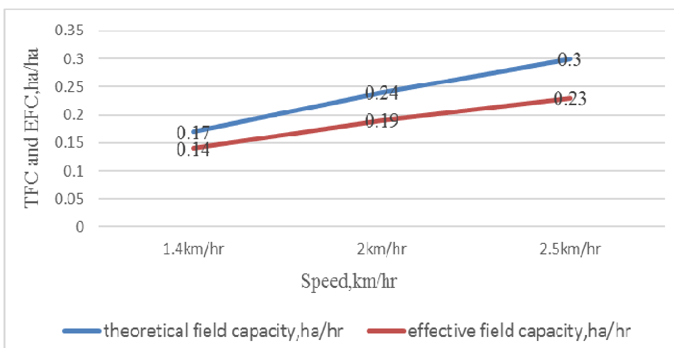

Figure 10. Effect of forwarding speed on theoretical and effective field capacity

Draft requirement

The draft requirement increased with increase in forwarding speeds with values 61, 67 and 69 kg on 1.4, 2.0 and 2.5 km/h speed, respectively.The data presented in Table 6 indicates that the operating speed of the walking tractor significantly affected the draft requirement. (See Figure 8)

Power Requirement

About 8.28 hp Power requirements were found the maximum for speed at 2.5 km/h and minimum power requirement of 2.93 hp was the observed speed of 1.4km/h. The Figure 9 shows that the power requirement increased with increase in speed.

Theoretical and Effective Field Capacity

Theoretical field capacity and effective field capacity mean values were obtained at different operating speeds shown in Table 6. The minimum value of theoretical field capacity observed at 1.4 km/hr speed was 0.17 ha/hr and maximum values at 2.5 km/hr speed was 0.3 ha/h. The values of effective field capacity on 1.4, 2.0 and 2.5 km/hr were 0.13, 0.19 and 0.23 ha/h, respectively. The Figure 10 show that theoretical and effective field capacity increased with increase in speed.

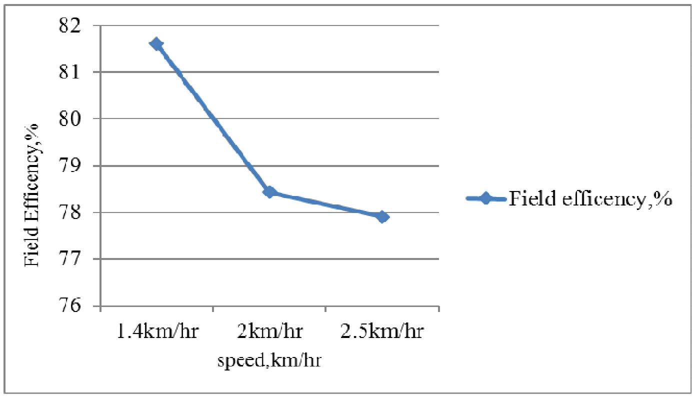

Figure 11. Effect of forwarding speed on field efficiency

Field efficiency

The field efficiency mean values obtained were listed above in Table 6. The minimum field efficiency occurred at 2.5 km/hr operating speed was 77.91% and the maximum field efficiency noticed that at a speed of 1.4 km/hr was 81.61%. The Figure 8 shows that field efficiency decreased with increased in speed. Rangapara (2014) suggested that the field size was decreased; the number of passes of the drill increased too, which leads to increase in time losses and gave lower values of field efficiency. The highest 82.48 % field efficiency was observed at a lower speed. The major reason for the reduction in field efficiency by increasing forward speed was due to the less theoretical time consumed in comparison with the other test plots.

CONCLUSIONS

The field testing of walking tractor drawn wheat drills was carried out at the field of MARC. Three plots of 10 m × 22 m (size) were selected for a field test. The field was well prepared which was 15 cm deep, firm, fine structure, smooth and level, relatively free of surface trash. In the Preliminary test, walking tractor drew wheat drills was operated with 1.4, 2 and 2.5 km/h speed.

Walking tractor drawn wheat drills works satisfactorily in the field with required seed rate, seed uniformity with minimum damage to the seed. The operating speed of 2.5 km/h speed was suitable for sowing and gives desired seed rate, seed uniformity, and spacing.

The theoretical field capacity and actual field capacity were 0.3ha/h and 0.25ha/h, at an average speed of 2.5 km/h for shovel type furrow opener respectively and the average field efficiency was 77.9 percent. Under normal moisture content (13%) the slip was found to be only 8.67% of a diameter of the ground wheel of 50cm.The average depth placement of seed and spacing between rows were obtained as 3 to 5cm and 20 cm respectively. The plant population of 377 per m^2 was obtained. There was no visible damage notice during the field test.

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