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Performance of Single Axle Tractors in the Semi-Arid Central Part of Ethiopia

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አህፅርኦት

የሶስት ባለ አንድ አክስል ትራክተሮች ፍተሻና ጥናት በመልካሳ ግብርና ምርምር ማዕከል የተከናወነ ሲሆን ለፍተሻ ከተጠቀምንባቸው ትራክተሮች ውስጥ DF-12ና DF-15 ሞዴል ትራክተሮች ቻይና ስሪት ባለ 12ና15 ፈረስ ጉልበት ሲሆኑ ሶስተኛው Vari ሞዴል ባለ 6.5 ፈረስ ጉልበት ትራክተር ቼክ ሪፑብሊክ ስሪት ነው። ትራክተሮቹ ያላቸውን የስበት ጉልበትና የመሰክ ስራ ብቃት ለመገምገም በተካሄደው የቴክኒክ ፍትሻና የመስክ ሙከራ የተሰበሰቡት መረጃዎች ተተንትነው በዚህ ጥናት ተካተዋል። የመስክ ሙከራዎቹ በ(RCBD)የሙከራ ዲዛይን ሶስት ጊዜ ተደጋግመው የተከናወኑ ሲሆን የስበት ጉልበታቸውም በሲሚንቶ ወለል ላይ በሶስት ድግግሞሽ የተካሄደ ነው፡፡ በዚህም መሰረት ከDF-15 ሞዴል ትራክተር በ1ኛ፣ 2ኛና 3ኛ ማርሾች የተገኘው ትልቁ የመሳብ ሃይል ውጤት በቅደም ተከተል 2524.9, 2499.4 እና 2125.34 ኒውተን ነው፡፡ በዚሁ አቀማመጥ ከ DF-12 ሞዴል ትራክተር የተገኘው ውጤት 2268.81, 2111.38 እና 2061.24 ኒውተን ነው፡፡ በመስክ ስራ ሙከራም ከየትራክተሮቹ ጋር አብረው የመጡ ማረሻዎችን አቀናጅቶ በተከናወነው ፍተሸ ከ DF-15ሞዴል ትራክተር የተሻለ የእርሻ ጥልቀትና የመስክ ስራ ብቃት እንዲሁም ከ DF-12 ሞዴል ጋር ተቀራራቢ የነዳጅ ፍጆታ ተገኝቷል፡፡ በተቃራኒው በባለ 6.5 ፈረስ ጉልበት ተራክተር በጣም ዝቅተኛ የመስክ ብቃት ውጤትና ከፍተኛ የነዳጅ ፍጆታ ተመዝግቧል። በተጨማሪም DF-15 ሞዴል ትራክተርና መደበኛውን የእንስሳት ስበት ሃይል በመጠቀም ጎነ ለጎን ታርሰው በተዘጋጁ የሙከራ ማሳዎች ላይ በበቆሎ ሰብል እድገትና ምርት ላይ የንፅፅር ጥናት ተካሂዶ የጎላ ልዩነት ባይታይም በቁጥር የተሸለ ውጤት በ DF-15 ሞዴል ትራክተር ተገኝቷል። ይህም ጥናት በእንስሳት ስበት ከሚከናወነው እርሻ ይልቅ በባለ 15 ፈረስ ጉልበት ትራክተር የተከናወነው የእርሻ ስራ የተሸለ ጥራት እንዳለውና ጊዜና ጉልበት እንደሚቆጥብ አሳይቷል። ይህም ጽሑፍ የአነስተኛ ትራክተሮችን ጥቅም ከእንስሳት ማቆያ እንዲሁም ቀለብና የተለያዩ ወጪዎች አንጻር ፍተሻ እንዲከናወን ያለውን ምልከታ ያቀርባል።

ቁልፍ ቃላት፡ ባለሁለት ጎማ ትራክተር፣ የስበት አቅምና የመስክ ፍተሻ

Abstract

Performance evaluation of three single axle tractors namely Dongfeng15 hp and 12 hp Chinese made walking tractors and Vari6.5 hp Czech Republic made, were conducted at the Melkassa Agricultural Research Center (MARC). Drawbar and field performance data were recorded and analyzed. The experimental plots were laid side by side in a randomized complete block design (RCBD). The maximum drawbar pull in Newton (N) generated by DF-15 tractor at 1500 engine rpm settings (three-fourth load) were 2524.9, 2499.4 and 2125.34 in 1st, 2nd and 3rd gears respectively. In the same order maximum drawbar pull for DF-12 tractor were 2268.81, 2111.38 and 2061.24N. Similarly field performance tests conducted on equipment test field at MARC indicated highest average field capacity, field efficiency and ploughing depth for DF-15 tractor but least for Vari tractor which consumed much higher fuel per unit area than the two DF models. Consequently from the standpoint of pulling capability and operational efficiency, DF-15 model tractor (WT) was preferred and advanced for comparative agronomic evaluation with conventional animal power technology (AP).The result showed that grain yield(kg/ha) 2.386 and 2.184 (ton/ha) respectively for WT and AP were not significantly different (P<0.1).

Key words: two wheel tractor, evaluation, drawbar, field performance

Introduction

On average the agricultural sector accounts for 42.9% gross domestic product and generates over 90% of the foreign exchange (CSA, 2011). The total area under cultivation is about 18.5 million hectares, and more than 95% of it being cultivated by small holder farmers owning less than one hectare on average. Crop production has been carried out with power generated from human and draft animals using traditional plough and inefficient hand tools as used by their forefathers. Animal husbandry is an integral component of Ethiopian agriculture.

Farm power sources are categorized into human, animal, mechanical and a combination of them (FAO 2006). Since ancient times animal power has been the predominant power available for tillage, threshing and rural transport to the Ethiopian farmers. They are considered to be affordable, practical and easy with low level of maintenance and operation. Furthermore they are born and reared in the village system maintained on the feed and fodder available locally. Their dung is also used as indirect source of energy and farmyard manure. One of the limiting factor to crop production. On the other hand, relying completely upon manual and animal power constrain farmers by power limitations. Shortage and in efficient use of farm power limits the total area under cultivation and is responsible for low crop yield due to untimely-performed operations such as planting, weeding and harvesting, (Giles, 1975; Stout, 1990; Sims and Kienzle, 2006). Most farmers carry out mixed cultivation by growing pulses, oil crops and vegetables in addition to cereal cultivation. The cultivation calendar of farm operations for these crops commences with beginning of the rainy season with many operations overlapping with regard to the time period in which they are conducted. Baudron et al. (2015) reported up to 1% per day yield penalty incurred by delayed sowing and weeding for many crops which shows the importance of timeliness of agricultural operations. In order to enhance the productivity, this energy shortage should be fulfilled by adequately supplementing the draught animals with the use of inanimate energy resources.

The Ethiopian government has adopted agricultural-led industrialization as central plank of its development program, with a focus on growth of productivity in the sector. Many studies reported benefits of more production and productivity from increased farm power/energy (Faleye et al., 2012; Jekayinfa, 2006; Singh, 2006).Apart from improved crop yield, the increased usage of farm power for cultivation creates further demand for related agricultural machinery for harvesting, storage and to add value to primary products and so generates employment opportunities and income potential along the value chain (Sims, et al., 2016). Stout (2000) stated that, to ensure an adequate and safe food supply for expanding world population tractor is the prime source of power in agricultural mechanization in the developing countries. The experience of China, India, Thailand, Pakistan and other Asian countries in recent years also indicate the intensification of subsistence agricultural production associated with increased power utilization. In this regard it is clear that modern mechanization plays an important role as an essential input to raise labor and land productivity and reduce drudgery. Furthermore, the decreasing number of draft animal per household in the highlands, the rise in the population and the increased price of oxen along with the feed shortage drive the farmers to search for alternative power source.

Two- wheel tractor also known as a power tiller, walking tractor, hand tractor or garden tractor is a multipurpose, tractor designed primarily for rotary tilling and other operations on small and medium farms. It can be used for a variety of land preparation activities with a range of implements available. Some of these include ploughing, harrowing, ridging leveling and transportation among other things. It can also be used as a power source for stationary machines such as threshers and millers. Field machines such as tractors constitute a major portion of the total cost of crop production. The proper operation of these machines is essential for profitable agricultural production. Therefore, performance data for tractors and implements under different soil conditions are important to select and efficiently use with matching implements. Since, draft requirements vary with implement size, soil type, speed of operation and depth of operation, information is needed about the capacity of the tractor as well as the likely load to be imposed on it. Hence, the study reports the technical performance and ploughing field efficiencies of single axle tractors for selecting and effective utilization of an optimum travel speed for a given pulling capacity along with other tractive performance indices. Specifically examines drawbar and field performances as well as give brief overview on the suitability of two wheel tractors to the Ethiopian condition.

Objectives

1. Test the drawbar and field performance of available single axle tractors models with associated equipment
2. Compare agronomic benefits of single axle tractor and conventional animal drawn technology for maize production

Materials and method

Equipment used and verification of structures

The tested equipment were DF-15L (Chinese made), DF-12 (Chinese made) and Vari (Czech Republic made) 15hp, 12hp and 6.5hp walking tractors respectively. Run-in and laboratory inspection were done to examine if the power tillers are functioning well. The implements used for field performance trials were two furrow moldboard plough and rotary tillers matching to the power tillers. Except for the laboratory tests of the engine, important specifications of the tractors furnished by the manufacturers were checked and there is no variation with that of the manufacturer’s manual.

Determination of drawbar performance

In order to determine the drawbar horse power in different gears, pull- speed tests were carried out on clean dry concrete track for DF-15 and DF-12 walking tractors. The test track had two straight sides of 75 m length joined by semicircular curves at both ends, and had negligible slope from center to sides. During testing the engine was operated at a rated speed (2000 rpm) and three-quarter rated speed (1500 rpm). The inflation pressures of the tyres were kept at 150 kPa as recommended by the manufacturer. The tests were conducted in three gear settings, i.e., first, second and third, because walking tractors mounted with implements are normally operated in these three gears. To assess the performance of the walking tractor, parameters measured, recorded and calculated include draft and drawbar power, wheel slip, engine rpm, forward speed, and fuel consumption. They were measured as described below with testing equipment in the possession of agricultural engineering research division at MARC.

a. Drawbar pull and wheel slip

Drawbar pull were measured by hitching a loading sledge, developed by MARC, to the power tiller using strain gauge dynamometer (proving ring type load cell) with a capacity of 0-5000 N. The two ends of the load cell were mounted through articulated eye joints. The loads on the power tiller were varied by varying the load on the drawn sledge. The bridge output of the load cell was connected to the analog indicator unit (Figure.1) and a digital remote read-out voltmeter setup was connected to the output of analog indicator to convert analog into digital reading that displays drawbar value in millivolts (mV). During this test, load gradually increased to the predetermined wheel slip range set as a limiting factor and the line of pull was maintained horizontal at 30 cm above the ground. The conversion of millivolt in to drawbar force (N) was done by calibration with known weight and finally the relation between mV and drawbar force was derived (Figure. 1). The indicator unit directly indicated the draft of the power tiller. The load cell and load indicator were calibrated in the laboratory before and after use for every test. Wheel slip was calculated by counting the wheel revolution while traveling under load and at no load using Equation. (1).

$$S = \frac{N_0 - N_1}{N_0} \times 100 \qquad \text{(Equation.1)}$$

Where,

S = wheel slip, %;
N_1 = the advance under actual load conditions per wheel or track revolution, m
N_0 = the advance under no load conditions per wheel or track revolution, m

The experimental data were analyzed to obtain empirical equations which relate the different drawbar performance parameters. Thus, polynomial regression equations with a high coefficient of determination (R^2) were used to calculate drawbar pull and power at 6% wheel slip in all possible combinations of the two engine speeds and three gear settings.

Figure 1. Analog indicator of drawbar force (left) and calibration of the load cell (right)

b. Measurement of engine and machine forward speeds

The rated speed of the engine was 2000 rpm. The speed of the engine was set at the rated speed and three fourth rated speed with the help of digital non-contact type tachometer of 0 to 9999 rpm capacity having a least count of 1 rpm. The average forward speed ($m.s^{-1}$) of the tractor is determined from the mean of five readings of the time taken by the tractor using stop watch, while travelling 10 revolution of wheel distance.

c. Measurement of fuel consumption and specific fuel consumption

Fuel consumption ($lit.hr^{-1}$) of the tractor was measured by mounting an electronic fuel flow meter (Forment electronic fuel flow monitor, England) between the fuel tank and the fuel injection system. Consumption of diesel fuel in liter per hour was recorded for the tractor under different engine rpm at stationary condition after an interval of 30 min to minimize the effect of heating of the engine and variation in temperature of the diesel fuel. The specific fuel consumption ($L.kwh^{-1}$) of the tractor was calculated by dividing the value of fuel consumption ($L.h^{-1}$) with drawbar power (kW).

Field performance test

a) Trial site and setup

The initial field tests were carried out on all types of tractors at the equipment test field of Melkassa Agricultural Research Center, located 17 km south of Adama, during 2011 cropping season. It has an altitude of 1550m above sea level and its daily maximum temperature becomes very high during the months of March to June, during which the temperature can reach as high as 34.5ºC. The mean annual temperature is about 28.5 ºC. Melkassa has a highly variable rainfall that ranges between 500 and 800 mm annually. Each tractor were tested on an area of 240 m^2 (40 m x 6 m) laid side by side in a randomized complete block design with three replications. The test were conducted focusing on major tillage operation using matching implements on silty loam soil type, on which small tractors are expected to perform effectively. From the initial field test result the 15hp walking tractor (model DF-15) was found to be better than the other tractors and hence it was advanced for further agronomic evaluation in comparison with conventional practice.

b) Measurement of field performances parameters

In order to know the potential for the adoption of the tractor field performance parameters like working depth and width, travel speed, percent slip and fuel consumption during ploughing were determined according to the Test Procedure for Agricultural Equipment (Friew and Seyoum, 1994) with slight modification on plot size and the distance marked in the plot. The test was performed with two furrow moldboard plough with the engine throttle adjusted to obtain three forth rated engine speeds. The gear of the tractor was so selected that the forward speed is optimum for satisfactory control of the two wheel tractor.

The average field speed ($m.s^{-1}$) of the tractor is determined from the mean of five readings of the time taken by the tractor using stop watch, while working a 20m distance marked in the plot. Average width of ploughing was determined by taking five successive measurements from three reference points along the furrow using steel tape. The depth of work, were measured by steel scale in several spots of the tilled area. Wheel slip was calculated by counting the wheel revolution while traveling under load and at no load using Equation (1) above. The fuel required for each tillage operation was determined by filling the tank to full capacity before and after the test. Amount of fuel refilled after each test is the fuel consumption for the test noting the time required to complete the area of the test plot.

Field capacity for each test was calculated by dividing the total area worked by the period of time spent from the beginning of the first furrow pass to the end of the last one. Field efficiency for each test plot was calculated as the ratio of the area that the tractor completed to the area that the tractor would work operating at the average speed of the test and using the nominal width of work as shown by the following formula.

$$FE = 100A_w / VW\Delta T \text{ (Equation.2)}$$

Where:

FE = field efficiency (%); A_w = worked area during the test (m^2); ΔT = recorded period of time (s); W= nominal working width (m) and V = average speed (ms^{-1})

c) Agronomic evaluation

For agronomic evaluation the land was divided into two equal strips thus there were 2 treatments and 3 blocks established on plot size of (L×W) 40m×6m. The treatments (i) walking tractor (WT) and (ii) conventional animal power technology (AP) were arranged in a randomized complete block design. AP practice is characterized by 3 repeated plowings with traditional oxen drawn plow '*Maresha*'. The last plowing was done on the date of planting. In WT practice the land were plowed once with moldboard plow followed by rotary tilling on the date of planting employing DF-15 walking tractor as power source.

Melkassa-II maize variety, an intermediate maturing maize variety and potential grain yielder (5-6 $ton.ha^{-1}$) in low moisture areas, was used for the treatments. The row spacing was 0.75 m. Sowing was done manually at 1 to 2 seeds per station and desired plant stand was obtained by thinning the stand when the crop was at 3-4 leaves stage. Di-ammonium phosphate fertilizer (N: P: K 18:46:0) was applied at the rate of 50 kg.ha^{-1} at planting. Planting was done on May12th 2010. Plots were weeded twice by hand each time weeds reached more than 10 cm in height.

Results and Discussion

Drawbar performance

The ability to pull various types of implements is a primary measure of tractors effectiveness. Drawbar power, the most commonly used power outlet of agricultural tractors is a function of draft and speed. Table 2 presents the results of maximum drawbar pull with the corresponding forward speeds and drawbar power emanated from drawbar performance test of DF-15 and DF-12 tractor models. Because of similarity of the observed trends drawbar performance relationship curves only for DF-15 model tractor was shown in Figure. 2, 3&4.

Table 1. Drawbar performance of Df-15 and DF-12 two wheel tractors

Tractor	RPM	Gear	Max. Pull(N)	Speed (m.s^{-1})	Max power (W)	Limiting slip (%)
DF 15	1500	I	2524.9	0.26	656.47	13.0
		II	2499.4	0.47	1174.72	11.2
		III	2125.34	0.76	1615.26	7.3
	2000	I	2362.37	0.35	826.83	9.5
		II	2293.23	0.62	1421.80	9.1
		III	2173.34	1.02	2216.81	7.0
DF 12	1500	I	2268.81	0.27	612.58	10.2
		II	2111.38	0.45	950.12	10.9
		III	2061.24	0.77	1587.15	7.0
	2000	I	2088.54	0.34	710.10	12.0
		II	2249.98	0.62	1394.99	8.4
		III	2108.97	0.97	2045.70	7.4

Drawbar pulls versus wheel slip

The pull-wheel slip relationship of the two wheel tractor is graphically represented in Figure 2. The behavior of drawbar pull curves showed similar trends for both engine speeds. As observed from the curves values of drawbar pull do not vary considerably while operating the two-wheel tractor in different gears. Further increase in load tended to cause abrupt drop in forward speed due to excessive wheel slip. Previous studies also reported a positive correlation between drawbar pull and wheel slip. The empirical equations developed with second order polynomial regression fitted well for drawbar pull versus wheel slip parameters in all trials. These equations are valid for the wheel slip values between 0 and 15%.According to Zoz, (1970) drawbar performance values of 6% wheel slip on concrete and those required for best tractive efficiency under field conditions were nearly the same. Based on pull- wheel slip empirical equations DF-15 tractor is capable of pulling 1594.61, 1556.18 and 1518.67N in first, second and third gears at 6%wheel slip and 1500 engine rpm. In the same order drawbar pull values at an engine speed of 2000 rpm were 1577.16, 1660.91 and 1718.77 N. At this wheel slip the highest drawbar pull value were observed in the first gear setting at engine speed of 1500 rpm, while it was the third gear at engine speed of 2000 rpm. The pull-slip characteristic of the tractor indicates the speed limits and load in each gear of the tractor which can be adapted for different farm operations. The drawbar load tends to reduce forward speed of the tractor in lower gears due to increase in wheel slip and due to engine stall in higher gears.

Table 2. Values of the coefficients co-relating drawbar pull, drawbar power and forward speed with wheel slip on concrete test track

Parameters	Gear	Coefficient			R^2
		a	b	c	
Drawbar Pull					
1500 rpm	I	-12.93	336.6	40.99	0.996
	II	-11.90	326.6	24.98	0.991
	III	-12.61	323.2	33.43	0.995
2000rpm	I	-12.35	332.3	27.96	0.985
	II	-15.65	369.0	10.31	0.976
	III	-19.43	400.3	16.45	0.972
Drawbar power					
1500 rpm	I	-4.28	97.83	12.51	0.995
	II	-7.3	168.5	13.38	0.990
	III	-12.44	278.8	30.88	0.994
2000rpm	I	-5.07	123.3	12.3	0.980
	II	-11.37	245.6	9.56	0.970
	III	-23.4	442.9	20.88	0.970

Forward speed and wheel slip

Slippage decreases with an increase in tractor speed under different gear settings at rated speed (i.e., 2000 rpm) and three-fourth rated speed (i.e., 1500 rpm). The general form of the empirical equation developed to relate forward speed and wheel slip is represented by a linear regression equation given below. Determination (R^2) ranged from 0.995 to 0.998 and 0.963 to 0.999 at 1500 and 2000 rpm respectively. The equation is valid for wheel slip values between 1 and 15% for all gear settings at both 1500 and 2000 rpm engine speeds. The values of forward speed obtained at 6% wheel slip were 0.278m.s^{-1}, 0.488m.s^{-1}, 0.825m.s^{-1} at three-fourth and 0.366m.s^{-1}, 0.643m.s^{-1} and 1.062m.s^{-1} at rated speed in first, second and third gears respectively. Travel reduction affects the traction efficiency of any tractive device. Excessive slip can cause a considerable increase in fuel consumption and lower field efficiency.

$$V = aS + b \qquad \text{(Equation.3)}$$

Where, V= forward speed; S=wheel slip %

a and b are constant(coefficient) with (+) or (-) sign shown table

Table 3. Values of the coefficients co-relating forward speed and wheel slip on concrete test track

Engine speed, rpm	Gear selected	Coefficient		Coefficient of determination, R^2
		a	b	
1500	I	-0.003	0.296	0.998
1500	II	-0.006	0.524	0.995
1500	III	-0.009	0.879	0.996
2000	I	-0.003	0.384	0.999
2000	II	-0.01	0.693	0.963
2000	III	-0.011	1.128	0.999

Drawbar power versus wheel slip

The positive correlation between drawbar power (P) and wheel slip (S) is shown in (Figure 3). Drawbar power increased with increased wheel slip in the range 0 to 15 %. The data obtained from the testing of the two wheel tractor at engine speeds of 1500 rpm and 2000 rpm were analyzed and second degree polynomial regression equation was employed to establish relationship between drawbar power and wheel slip. The data showed good correlation of drawbar power and wheel slip in all trials, with high coefficients of determination ranging from 0.969 to 0.995. It was observed that drawbar pull considerably varied while operating the two-wheel tractor in different gears. The results of the study also indicated that the drawbar power generated at 6% wheel slip and engine speed of 1500 rpm were 445.10, 761.54 and 1255.84W in first, second and third gears, respectively. The respective values of drawbar power at 2000 rpm engine speed were 569.54, 1073.84 and 1829.88W. The increase in the drawbar power at higher engine speeds was due to greater forward speed of the two-wheel tractor. Since drawbar power is a function of draft and forward speed, there was a significant increase in the drawbar power in higher gears and at higher engine speed.

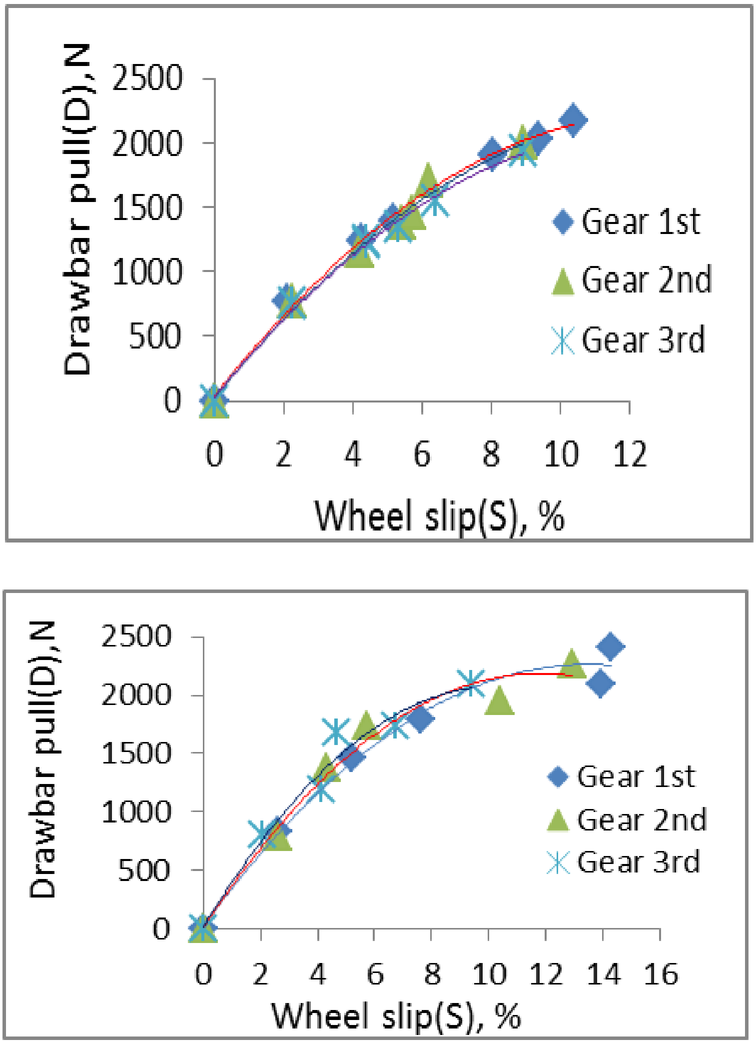
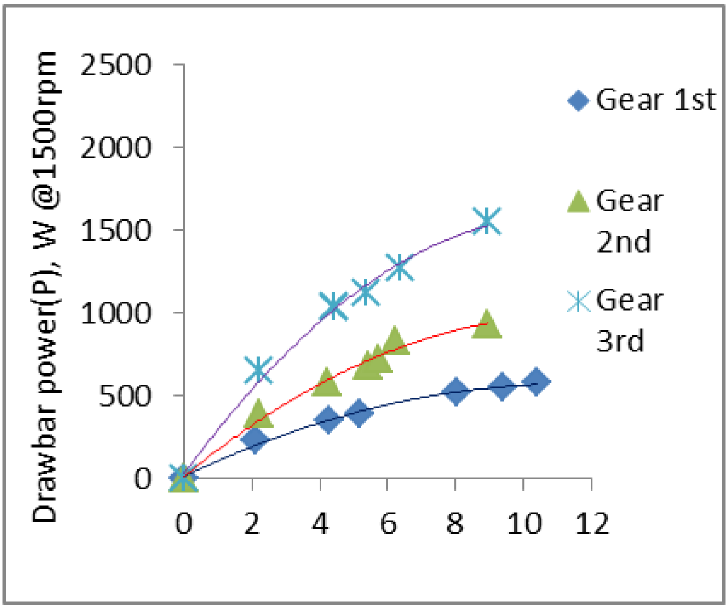


Figure 3. Relationship between drawbar pull and wheel slip in 1st, 2nd, and 3rd gear at 1500 (upper) and 2000 (lower) engine rpm for Df-15 model walking tractor.



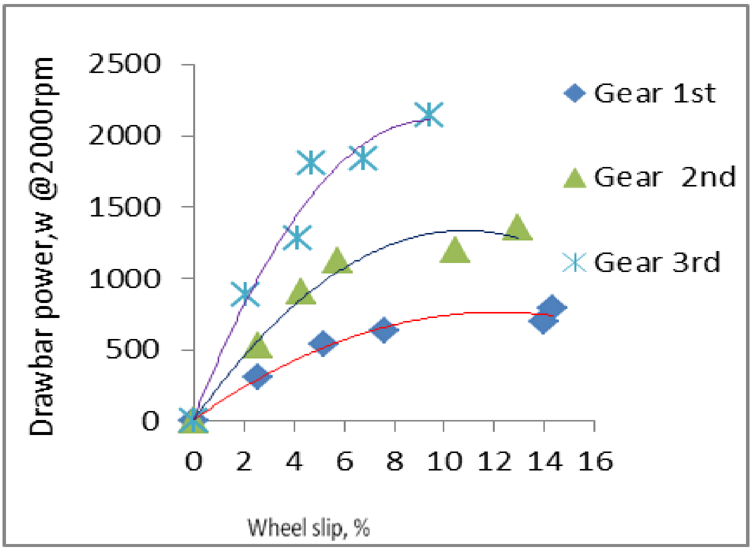


Figure 4. Relationship between drawbar power and wheel slip in 1st, 2nd, and 3rdgear at 1500 (upper) and 2000 (lower) engine rpm for DF-15 model walking tractor

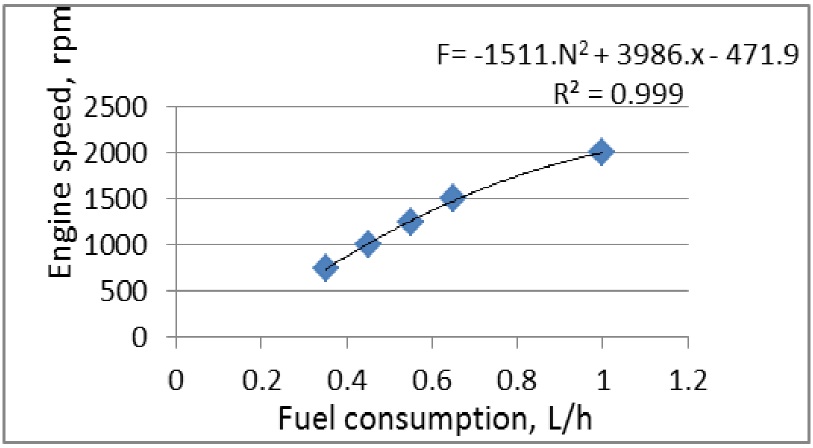


Figure 5. Fuel consumption rate of DF-15 walking tractor engine

Fuel consumption

Figure5indicates fuel consumption of DF-15 model walking tractor. Fuel consumption increased from 0.35 to 1 liter per hour with an increase in engine speed from 750 to rated engine speed (2000 rpm).

Field Performance of Two-Wheel Tractor

The soil and field condition during ploughing test and field performance results of the two wheel tractors for plowing and harrowing operation were shown in Table 4 and 5 respectively. Effective field capacity of the tractors with matching two furrow moldboard plough were 19.7, 19.9 and 30.84hr.ha^{-1} respectively for DF-15, DF-12 and Vari tractors. The field capacity of a machine is a function of its width, speed and efficiency of operation. Tractor model Vari achieved least results for field capacity despite the higher speed of operation than the two DF model tractors which showed equivalent field performance. This could be explained by lower values of width of cut, field efficiency and the higher travel reduction associated with Vari tractor during tillage operations. Fuel consumption in liter per hectare during ploughing was lowest for DF-15 flowed by DF-12model tractors. Fuel consumption of Vari tractor is about 70 to 90% higher than DF model tractors. This could be associated with higher travel reduction of Vari tractor during tillage operations. During ploughing test with moldboard plough, all tractors showed excessive wheel slip than the optimum performance (assumed to be 10 to 15%). Often a tendency to dig-in and spin particularly for Vari tractor was observed along each furrow which demanded a lifting up fatigue force from the operator. Sometimes difficulties which exerted unnecessary strains on the operator shoulder were encountered to counteract side force while steering the two wheel tractor. Quality of tillage from the view point of soil pulverization and stubble mixing was found satisfactory.

Table 4. Physical properties of soil

Plots	1	2	3
Operation	plowing	plowing	plowing
Plot size, (L×W) m2	40 × 6	40 × 6	40 × 6
M.C. (%)	21.60	11.11	7.67
B.D (g.cm3)	1.72	1.51	1.41
C.I (kN.m2)	0.`46	0.42	0.67
S.S(MPa)	0.028	0.038	0.094
Weed condition	Small dry grass weeds, slight crop residue	Small dry grass weeds, slight crop residue	Small dry grass weeds, slight crop residue

M.C.= moisture content, B. D.= bulk density, C. I.= penetrometer resistance/cone index, S.S.= shear strength before tillage

Table 5. Field performance of DF-15, DF-12 and Vari walking tractors on plowing operation

Operation	parameter	DF- 15	DF-12	VARI
ploughing	Depth of plowing (cm)	15.23 ± 1.23(a)	14.63 ± 0.62 (a)	13.69 ± 1.39(a)
	Fuel (lit.ha-1)	18.42 ± 3.73 (b)	20.41 ± 0.72(b)	34.17 ± 10.57(a)
	Slip (%)	39.35 ± 4.11(b)	42.89 ± 4.57(b)	48.70 ± 10.17(a)
	Field Capacity (hr.ha-1)	19.75 ± 0.60 (b)	19.90 ± 0.77(b)	30.84 ± 2.01(a)
	Field Efficiency (%)	89.94 ± 0.32 (a)	89.40 ± 8.44 (a)	76.80 ± 22.69(a)
Harrowing with rotary tiller	Average depth of tillage (mm)	62.00 ± 14.8		
	Field Capacity ($hr.ha^{-1}$)	6.90 ± 0.38		
	Fuel ($lit.ha^{-1}$)	7.10 ± 0.92		

Letters inside the bracket indicate mean separation test within the row. Means followed by the same letter are not significantly different at p<0.01;

Agronomic performance

It appears that similar seedling emergence and plant stand count were observed between treatments. Crop yield and above ground biomass were numerically higher than traditional animal drawn technology though not significantly (P<0.1) different (Figure4). This can be explained by a deeper plowing with the use of moldboard plow attached to the walking tractor which facilitated more moisture holding and better root development.

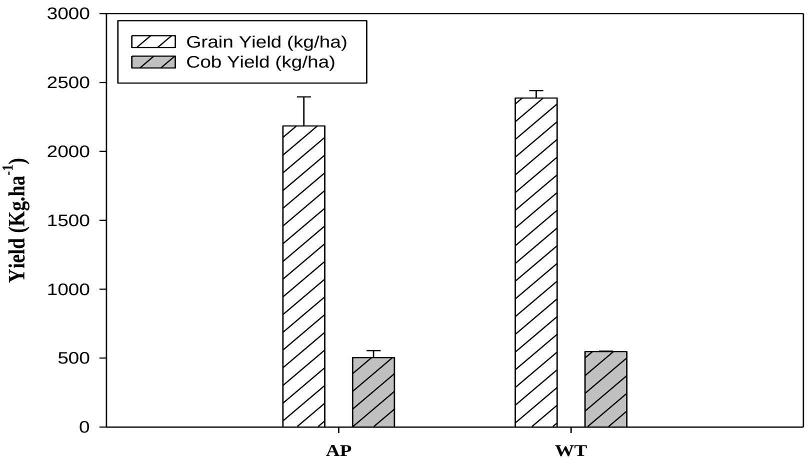


Figure 4 Grain and biomass yield at Melkassa, 2011

Summary and General Consideration

As the power of the tractor is commonly utilized, at the drawbar, the paper examined drawbar performance of DF-12and DF-15 walking tractors on concrete test track and controlled field test of the three walking tractors (including Vari model) at Melkassa agricultural research center. Furthermore, animal power and single axle tractor technology were compared for agronomic benefits.

The results of drawbar pull, drawbar power, slip and forward speed at different gear and engine rpm settings showed that DF-15 tractor relatively performed better. Field performance of the three walking tractors indicated that average field capacity, field efficiency and ploughing depth were highest for DF-15 tractor but least for Vari tractor which consumed much higher fuel per unit area than the two DF models. Consequently with respect to evaluated drawbar and field performance parameters, the findings of this study indicated that DF-15 walking tractor was preferred among tested tractor models. Agronomic evaluation indicated that actual work rate of walking tractors for ploughing with moldboard plough and harrowing with rotary tiller were 19.7 $hrha^{-1}$ and 6.9 $hr.ha^{-1}$ respectively. Considering equivalent work quality (volume of soil disturbed), 3 to 5repeated ploughing were done for the corresponding animal powered conventional practice. This means the work rate of single axle walking tractor is 2.5 to3 times higher than the conventional animal power practice for field operations prior to planting.

Single axle tractors with PTO powered rotary tiller have gained general popularity in cultivating rice paddies where the soil requires lower tractive power. On the other hand soil tillage with drawn implements in rain fed farming exhibit two to eight times higher soil resistance than in wet rice paddy (HoltKamp*et.al,* 1990).Thus it is advisable to restrict single axle tractors to light soil types and wait for correct timing of ploughing when there is ideal soil moisture at the beginning of wet season.

In terms of costs and benefits the high cost standard tractors are capital intensive and beyond the reach of majority of Ethiopian individual farmers. Compared to these tractors the initial cost and consequently hourly cost of operation of small tractors is more adapted to the financial means of emerging individual farmers. Furthermore the highly fragmented and scattered land holdings in many parts of the country, also favor single axle tractors and therefore they could be a possible alternative to the use of animal traction. However an arrangement to provide custom hiring service for standard tractors by engaging unemployed rural youth could be an option which can go mutually in meeting the requirements like soil tillage in areas where there is hard black soils and other favorable conditions.

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References

Baudron, F.; Sims, B.; Justice, S.; Kahan, D.; Rose, R.; Mkomwa, S.; Kaumbutho, P.; Sariah, J.; Nazare, R. and Moges, G. 2015. Re-examining appropriate mechanization in eastern and southern Africa: Two-wheel tractors, conservation agriculture, and private sector involvement. Food Security. 7, 889–904.

CSA (Central Statistical Agency). 2011. Area and Production of Major Crops. Addis Ababa.

Faleye, T.; Adebija, J.A. and Farounbi, A.J.2012. Improving small-farm productivity through appropriate machinery in Nigeria. Int. Res. J. Agric. Sci. Soil Sci., 2, 386–389.

FAO (2006). Farm power and mechanization for small farms in sub-Saharan Africa, Agricultural and food engineering technical report 2.

Faidley, L.W. 1992. Energy and agriculture. In: R.C. Fluck (Ed), Energy in Farm Production, Elsevier, Amsterdam: 1-12.

Friew, K. and Seyoum, W/S. (ed) (1994). Test Procedure for Agricultural Equipments AIRIC, Nazareth.

Giles, G.W. 1975. The Reorientation of Agricultural Mechanization for the Developing Countries. In FAO Report on Effect of Farm Mechanization on Production and Employment; Food and Agricultural Organization (FAO): Rome, Italy.

Holtkamp Rodolf Lorenz and Jim.1990. Technical Center for Agricultural and Rural Cooperation (Ede, Netherlands). Small Four Wheel tractors for the Tropics and Subtropics: their role in Agricultural and Industrial Development. Deutsche Gesellschaftfür Technische Zusammenarbeit(GTZ); Weikersheim: Distributed by Magraf, Eschborn.

Jekayinfa, S.O. 2006. Energy consumption pattern of selected mechanized farms in Southwestern Nigeria. Agricultural Engineering International. The CIGR Ejournal, Manuscript EE 06 001, VIII.

Sims, B.G.; Kienzle, J. and Hilmi, M. Agricultural Mechanization: A Key Input for Sub-Saharan African Smallholders; Food and Agriculture Organization of the United Nations: Rome, Italy, 2016; in press.

Singh, G.2006. Estimation of a mechanization index and its impact on production and economic factors—A case study in India. Biosyst. Eng., 93, 99–106.

Zoz, F.M. 1970. Predicting Tractor Field Performance, For Presentation at the 1970 Annual Meeting ASAE

ANNEX 1 Main specification of the tested tractors

Verification of structures			
Tractor Model	**DF 15**	**DF12**	**VARI**
Engine type	Horizontal,4stroke, Single cylinder, liquid cooled, diesel	Horizontal, 4stroke, single cylinder, liquid cooled, diesel	Vertical,4stroke, single cylinder, air cooled ,gasoline
Rated output	15hp/11.23kw	12hp/8.98kw	6.5hp/4.87kw
Dimensions (mm)			
✓ Overall length	2650	2650	1890
✓ Width	970	970	780
✓ Height	1250	1250	1220
✓ Ground clearance	180	180	90
✓ Wheel track	780	780	600
✓ Tire size	6-00-12	6-00-12	5-00-12
Power transmission	Belt and gear drive	Belt and gear drive	Gear drive
➢ Number of forward gears	6	6	3
➢ Reverse gears	2	2	1
Brake type	Inner expanding wet type	Inner expanding wet type	Inner expanding dry type /shoes/