DETERMINATION OF FUEL CONSUMPTION RATE OF NIGERIAN ASSEMBLED TRACTORS

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CERTIFICATION

This is to certify that, the Determination of Fuel Consumption rate of Nigeria assembled tractors was carried out by KAREEM MUTAHIR ABIODUN under the supervision of ENGR. DR. M. G. YISA of the Department of Agricultural Engineering, School of Engineering and Engineering Technology, Federal University of Technology, Minna.

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DEDICATION

I solemnly dedicate this project to Almighty Allah (S.W.T) and to all prophets (PBUT).

ACKNOWLEDGEMENT

All thanks and glory be to Almighty Allah for His mercy and blessing on me since my existences to this present moment. And without being partial, ungrateful, and unrespectable, doubt not my profound and sincere gratitude to my H.O.D " My supervisor" ENGR. DR. M.G. YISA for his kindness, patience, constructive criticism and above all for supplying and injecting me from time to time knowledge and ideas to successfully carry out this project; Sir! I am grateful for your wisdom and time you spent with me. And as well, all my lecturers since I was admitted to this institution, mostly, the lecturers in Agricultural Engineering Department Sirs, your individual contribution is well appreciate. It also not my right to deprive MR. FABUNMI, MALLAM DAN-FULANI AND MR. SULEIMAN their appreciation for their kindly assistance they did have for me during my practical work Sir I am overwhelm.

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ABSTRACT

This present study shows the quantitative relationship on diesel fuel consumption of three makes of tractor on idle operation and the effects of speed, depth and width of cut on fuel consumption for fiat – 666 tractor during plough operation. The selected tractors for idle operation showed that fiat – 666 consumed 0.867 l/h, MF–185 consumed 1.167 l/h and steyr –8075 consumed 5.42 l/h at field operation the results obtained showed that the speed, width and depth of cut have significant effects on fuel consumption of the tractor during the ploughing operation. Thus, the higher value of steyr-8075 tractor due to different engine type, design and the faulty fuel system.

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CHAPTER ONE

INTRODUCTION

Fuel Consumption of farm tractors is governed by the amount of energy demanded at the drawbar or through the power take-off With the increasing use of farm machinery, farm tractors play an important role in enhancing the agricultural productivity . The farmers will not reach their full potential and objectives until a means is developed to find what leads to their losses The fuel consumption of tractors shares major portion of the tractors operating cost in which most of the farmers involved in mechanization often overlook, which at the end lead to substantial losses.

Diesel consumption of tractors depends upon age of tractors, annual use and labour cost of maintenance, but most farmers are unmindful, which make it difficult for them to estimate annual operating cost and /or fuel budgeting for a particular operation. In tractors, the ability of an engine to convert fuel into useful work varies with engine type, design, speed and loading, this leads to a significant variation in diesel fuel consumption by the tractors. This variation is more readily appreciated in terms of annual expenditure on fuel for farm tractors with similar power rating.

Diesel fuel consumption of tractors is often determined along with power measurement. This can be by measuring the rate at which the fuel is flowing to the engine by some type of fuel flow meter by measuring out a volume of fuel and recording the time required to consume this quantity and to use a measured mass of fuel. When the fuel consumed by the tractors is measured in volume, the consumption units are liter/KW hour (The measured fuel consumption should be related to the power output and "specific fuel consumption in litre per kiloWatt hour (L/KWhr), and if measured by mass the consumption units are kg/kWhour.

In economic evaluation of tractors operation in Nigeria, tractors value depreciate with age, which invariably is proportional to the rate of fuel consumption by the tractors. Among the variable factors that are directly proportional to the tractors usage and which have direct influence on fuel consumption by the tractors are: speed of operation, depth of cut, width of cut soil condition (soil moisture, texture and structure) and the tractor operator's skill. Hence, there is a need of developing a means of determining diesel fuel consumption of farm tractors using **fuel flow meter** calibrated in literes which could help in estimating tractors fuel consumption at a particular operation, with a giving design on fuel consumption.

1.1 OBJECTIVES OF THE STUDY

The objectives of the study is.-

1. To determine the quantitative relationship in diesel fuel consumption of three makes of tractors (Massey Fergusion (MF) -185, Fiat - 666 and Steyr - 8075 tractor)
2. To enable the farmers and tractor users to determine precisely the amount and /or range of fuel used in litre/hour or litre/hectare on a field operation.
3. To enable the farmers as well as tractor users to accurately budget cost of operation; in order to achieve maximum farm economy.
4. To estimating fuel requirements in preparing farm budget to ensure timeliness of field operations.

CHAPTER TWO

LITERATURE REVIEW

In most mechanized farms, economic management of power and machinery (Tractors) is often overlooked as a factor in farm profits, yet it is usually a most significant factor. Many of the mechanized farms run into losses, by which many of the farmers find it very difficult to state the factors which leads to their losses at end. Even, many of them may not be able to state with the degree of accuracy, the total annual cost or operating cost, and even to estimate the required fuel (diesel) in preparing farm budget to ensure timeliness of field operation.

Research has shown that both fixed factors and variable factors contributed to farmers losses. And among of the tractor operating costs that of fuel is the major item and is a direct out of pocket expense on the part of the farmers.

Igbeka (1986) investigated the economic evaluation of tillage operations in some mechanized farms in Nigeria using questionnaires and unexpected random visits to the operation sites. He found out that among the variable factors affecting the operating costs and farm economy that of the fuel has grater share and directly proportional to the machinery usage. He concluded that, "cost of plowing was highest, while that of ridging was marginally higher than that of harrowing". Just as a result of fuel consumed by each operation and also due to implement. weight

Bhattachanya (1981), carried out a research study on standardizing tractor field test with matching implement namely: two/three – bottom moud board plough mounted/trailed disk harrow and a 9 – tine cultivator. The plowing operation was carried out in the moisture range of 10 to 15% and harrowing operation in the moisture range of

6 to 14%. He concluded that the drawdbar specific fuel consumption ratio of both the tractors was 1.22 to 157 for plowing, 1.07 to 1.76 for harrowing and 1.32 to 2.29 for cultivation operation.

Frisby and Summer (1979) carried out a study on energy related data for selected implements using a John Deere 2630 diesel tractor. They found that the three-bottom mould board plough with 1.07m width of cut and 20.5cm dept of cut at the speed of 5.95 km/h on loamy soil consumed 20.62 l/h.. The tandem disk harrow having width of cut 3.97m and depth of cut 10.2 cm at the speed of 6.14km/h on loamy soil consumed 23.62 Uh.

Shetton et al (1979) studied the farm fuel use in Nebraska and found that the mean diesel fuel consumed for plowing was 17.49 l/ha; disking, 7.39 l/ha; and for harrowing 552 l/ha.

Bukhari and Baloch (1982) carried out a study on determination of fuel consumption of tillage implements. They found that the mould board plough operating on soft soil turned up more soil and consumed less fuel as compared with the operation on hard soil at almost the same speed of operation. And mould board plough proved more economical than the disk plow on soft soil at almost the same speed operation while disk plow, gave better performance on hard soil than the mould board plough at reasonable higher speed of operation. And the work rate of the disk harrow was much faster than the mould board plowing and disk plow on both soil with less depth of operation. They concluded that it would be better to operate the mould board plow and disk harrow in combination on soft soil and disk plow and disk harrow on hard soil.

Ancheta and Bautiosta (1986) conducted a test on work capacities and fuel consumption of Hand Tractors manufactured in the Philippines. Result show that the actual plowing capacity ranged from 0.098 ha/h to 0.25ha/h with an average of 0.14 ha/h (or 7.86 h/ha) and the field efficiencies ranged from 53.6 to 94.4 % with an average of 83.6%. Six of the hand tractor tested were gasoline – fed and the average fuel consumption was 2.49 l/h (18.73 l/ha) and a specific fuel consumption of 1.89 l/ha/hp. And the four diesel – fed hand tractors had an average fuel consumption of 0.82 l/h (6.12 l/ha) and an average specific fuel consumption of 1.22 l/ha/hp. They concluded that the hand tractors with diesel engines have lower fuel consumption.

In a survey conducted by Johnson as reported by Ancheta and Bautista (1986) on the performance and economics of the use of small equipment in the Philippines Results of the tractive type hand tractor studies show an average fuel consumption of 15.3 l/ha and an average actual field capacity of 12.9 h/ha (0.08 ha/h) for plowing operation.

Ancheta and Bautista (1986) also reported on the study carried out by Orcino on the economic aspects of imported hand tractors and ownership in Philippines. He reported that data on the fuel and oil consumption costs were based mostly on the recollections and estimates of the respondents as none of them made records of machine and labour performance. The study show that the actual field capacity of the machine (plowing and harrowing) was 44.1 h/ha (0.02 ha/h) and an average fuel consumption of 1.18 l/h.

In a test conducted by AMTEC of a front located power drive type hand tractor as it was reported by Ancheta and Bautista (1986) indicated that puddling work out-put of 16.7h/ha (0.06/h). The average fuel consumption was 1.04l/h

Kazmi and Ahmad (1996) developed mathematical models for diesel consumption of farm tractors in Allahabad district India Using HMT Zetor –2511,Escort 335, Massey Ferguson- 1035 and International B – 275. They concluded that all the models for different makes of tractor are adequate at 5% level of significance. And there is always high positive correlation between age of tractors and diesel consumption. As the age of the tractor increases, the diesel consumption increases.

Ajadi and Babatunde (1998) developed modeling equations for fuel consumption rate of Tractors during tillage operations – ploughing, using two-wheel drive tractor with a 2-bottom disc plough. They found that the speed, width and depth of cut have significant effects on fuel consumption of the tractor during the ploughing operation. The speed and width of cut during ploughing significantly increase fuel consumption of tractors as they are themselves increased through acceleration of disc angle setting. And the model equation developed for estimating fuel consumption for ploughing operations is simple to use as it depends on a predetermined area and rate of work.

Ancheta and Bautista (1986)reported a survey of 125 – tractors owners in Nueva Ecija province, Philippines, carried out by Maranan, show that two –wheeled tractor can finish plowing 1 ha of land in 11.2 h on the average.

Brian (1988) stated that the amount of fuel consumption of a tractor is governed by the amount of energy demanded at the drawbar or through the power take- off, and even for ploughing, the fuel consumption of an individual tractor varies considerable over the duty cycle and the average fuel consumption is only two thirds of the fuel consumption for peak power . He concluded that the required fuel for; ploughing is 15 l/ha, and heavy and light cultivation are 13 l/ha and 8 l/ha respectively.

CHAPTER THREE

3. 0 MATERIAS AND METHODS

3.1 MATERIALS AND EQUIPMENT

The following listed materials and equipment were used in order to successfully carry out this study and their full description are shown in table 1 below

S/NO	MATERIAL
1	Steyr – 8075 tractor
2	Massey Fergusion (MF) – 185 tractor
3	Fiat – 666 tractor
4	Disc Plough
5	Diesel fuel

Table 1: Description of main materials and equipment used.

S/NO	NAME	WIDTH (M)	SPECIFICATION
1	Steyr – 8075 tractor	-	Steyr –8075, two wheel drive tractor, 75 kw, three point hitch linkage system, 8 years old.
2	MF –185 tractor	-	Massey ferguson – 185, two wheel drive tractor 60 kW, three point hitch linkage system, 4 years old.
3	Fiat – 666 tractor	-	Fiat – 666, two wheel drive tractor 68 kW, three point hitch linkage system, 15 years old.
4	Disc plough	0.9	Mounted 3 – bottom MF disc plough 660mm disc diameter, Tilt and disc angle not adjustable as well as tail wheel.
5	Diesel fuel	-	Diesel fuel of relative density 0.85, 42000 – 45400 kj/kg calorific value.

The Instrument /Apparatus used to carry out the study are listed below

* Fuel flow meter
* Stop watch
* Scale rule
* Meter rule
* Electronic weighing balance,
* Air circulated oven

3.2 DESCRIPTION OF MAJOR APPARATUS USED

3.2.1 FUEL FLOW METER

This is an instrument used to measure the amount of fuel used by the tractor in litre/hour. It was built with 1mm steel metal plate of diameter 210mm and height of 266mm calibrated in litres. This has a total capacity of 9 liters, with rubber capillary tubes of 5mm diameter protruding directly from the tank and mounted on both sides to determine the fuel level and ease read – out. A cover was constructed for the fuel tank with 2 – holes at the top, 10mm, 60mm apart to accommodate the supply and return line. A cross bar was welded across the cover together with two bolts (6mm diameter) of 130mm length each welded at the extreme end. Through this, the fuel tank was connected directly into the constructed frame; which served as a guide and as well as, a means of mounting the fuel flow meter on the tractor through three bolted points. The supply line was used to supply fuel (diesel) from the fuel flow meter into the tractor fuel system and while the return line was used to return the excess/unburned fuel from the atomizer/injector to the fuel flow meter. As shown in plate 1.

3.2.1.1 CALCULATION FOR THE CAPACITY AND THE TOTAL WEIGHT OF THE FUEL FLOW METER

Height = 266mm

External diameter = 210mm (D_1)

Internal diameter = 208mm (D_0)

$$\text{Internal Area} = \frac{\pi (D_0)^2}{4}$$

$$= \frac{\pi (208)^2}{4} = 33962.24\text{mm}^3$$

Internal volume (capacity of the Tank)

= Internal area x height

= 33962.24 x266

= 9033.9558cm³

$$\text{Capacity of the Tank (in litre)} = \frac{9033.9558}{1000}\text{(litre)}$$

= 9.033 litre

≈ 9 litre

3.2.1.2 WEIGHT OF THE FUEL (DIESEL)

The weight of the diesel fuel in the Tank

= litre * Relative density of the fuel (diesel)

= 9.033 x 0.850

= 7.7kg

= 7.7 *9.81

=75. 3N

This implies that 9. Litres of diesel fuel is equivalent to 65 N in weight.

3.2.1.3 WEIGHT OF THE TANK

External volume of the Tank $= \dfrac{\pi (D_1)^2 * h}{4}$

$= \dfrac{\pi (210)2 \times 266}{4}$

$= 34618.5 \times 266$

$= 9208521 \text{ mm}^3$

$= 9.2085 \times 10^{-3}$

Volume of the thickness = External volume – Internal volume

$= 9.2085 \times 10^{-3} - 9.0339 \times 10^{-3}$

$= 175 \times 10^{-6} \text{ m}^3$

Weight of the Tank = Volume of the thickness x density

$= 175 \times 7850 \times 10^{-6}$

$= 1.37$

$\approx 1.4\text{kg}$

$= 1.4 \times 9.81$

$= 14 \text{ N}$ .... (1)

3.2.1.4 WEIGHT OF THE UPRIGHT AND CROSS BARS

Volume of the bar $= 140 \times 20 \times 3$

$= 8400 \text{ mm}^3$

$= 8.4 \times 10^{-6} \text{ m}^3$

Weight = Density x Volume x Acceleration due to gravity

$= 7850 \times 8.4 \times 10^{-6} \times 9.81$

$= 0.65 \text{ N}$

:- Total weight of the bars = 0.65 x 8

= <u>5.2N</u> .... (2)

3.2.1.5 WEIGHT OF THE SUPPORTING BASE

Diameter = 215mm

Thickness = 1.5mm

Height = 30mm

Volume = $2\pi r \times h \times$ thickness

= $2 \times 3.14 \times 107.5 \times 30 \times 1.5$

= $3.03795 \times 10^{-5}\ m^3$

weight = $7850 \times 3.03795 \times 10\text{-}5 \times 9.81$

= 2.34N ....(3)

3.2.1.6 WEIGHT OF THE BRACKET

Volume = $30 \times 30 \times 3$

= $2700mm^3$

= $2.7 \times 10^{-6}\ m^3$

Weight = $7850 \times 2.7 \times 10\text{-}6 \times 9.81$

= 0.21×2

= 0.42N .... (4)

1.7 WEIGHT OF THE UPPER CROSS BAR

Length = 295mm

Width = 20mm

Thickness = 3mm

Volume = 295 x20 x 30

= $17700mm^3$

= $1.77 \times 10^{-5}\ m^3$

Weight 7850 x 1.77 x 10-5 x 9.81

= 1.4 N .... (5)

:.1.8 WEIGHT OF THE COVER

Volume $[(2\pi rht) + (\pi r^2 t)]$

$= [(2 \times 3.14 \times 107.5 \times 1.5) + (3.14 \times 107.5^2 \times 0.5)]$

= 30379.5 +181343.3mm

$=48522.8mm^3$

$=4.8228 \times 10^{-5}\ m^3$

Weight = $4.85228 \times 10^{-5} \times 7850 \times 9.81$

= 3.74 N .... (6)

3.2.1.9 WEIGHT OF THE BOLTS

Length = 120mm

Diameter = 5mm

Volume = $\pi r^2 l$

= $3.14 \times (2.5)^2 \times 120$

= $2355 mm^3$

= $2.355 \times 10^{-6} m^3$

Weight = $2.355 \times 10^{-6} \times 7850 \times 9.81$

= 0.1813×2

= 0.4N .... (7)

3.2.2.0 WEIGHT OF THE BASE BRACKET (2 PIECES)

Volume = $20 \times 30 \times 3$

= $1800 mm^3$

= $1.8 \times 10^{-6} m^3$

Weight = $7850 \times 1.8 \times 10^{-6} \times 9.81$

= 0.14N

Total weight = 0.14×3

= 0.42 N .... (8)

Therefore , the total weight of the fuel flow meter is the addition of

(1) - (8) = 28 N

Total weight of the fuel flow meter when filled with diesel fuel will be equal to 75.3 + 28) N

103.3N ≡10.5kg

3.2.2 STOP - WATCH

This was used to determined the initial and final time taken for a tractor to perform one replication, the time is usually taken in minutes and seconds.

3.2.3 SCALE AND METER RULE

Scale rule was used to measured the depth of cut in "cm" of the disc plough randomly, while the meter rule was used to measure the width of cut in "cm" and the entire field length in "m"

3.2.4 ELECTRONIC WEIGHING BALANCE

This is an electronic instrument used to determine the initial and final weight of the field soil samples before and immediately after oven drying

3.2.5 AIR CIRCULATED OVEN

This was used to dry the water present in the soil sample. To do this the oven was set at 105^0C and drying was done for 24 hours.

3.2.6 MEASUREMENT OF SPEED OF OPERATION

Speed of operation was calculated by the time taken for the tractor to travel through a length of 145m. It is given as the ratio of the distance traveled in meter (m) to time taken in minutes (min).

3.3 EXPERIMENTAL PROCEDURE

There makes of tractors; MF – fiat –666 and steyr - 8075 were used to carry out the experiment at idle operation. A field operation was performed using fiat –666 tractor to mount MF -3 - bottom disc plough. A site was located in the university permanent site, six soil samples were collected to determined the moisture content (table 2) by oven dry method. A fuel flow meter that was constructed and graduated in litres served as tractor fuel tank. The fuel flow meter was mounted on the tractor and connected directly through fuel supply line into the tractor fuel lifting pump, and while the remaining line (return line) was connected to the injector/atomizer to return the excess fuel to the fuel flow meter..

Three replications at 30 minutes were carried out for each tractor at an idle operation, the time taken was recorded in minutes using stop watch and the mean fuel consumed for each tractor was found in litre/hour (l/h). In the field operation (ploughing), six tests of 145m field length were performed with slightly varying tractor speed (slow field speeds). For each replication, the time taken was noted/recorded in minutes, five different depths of cut and width of cut in "cm" were taken using metre rule and scale rule and the average value was found. The time taken per each trip was used to calculate the tractor speed in (km/h) and the fuel used was read directly form the fuel flow meter (l/min) then calculated to fuel consumed in (l/h).

CHAPTER FOUR

) RESULTS AND DISCUSSION

The tables below show the results obtained from the experiment conducted on idle operation (Table 3), Field Operation (Table 4) and the mean moisture content of the filed soil (Table 2).

able 2: Soil moisture content of test soil.

5oil sample number	Weight of wet soil (g)	Weight of dry soil (g)	Soil moisture content (%0
1	240.5	200.5	16.6
2.	263.4	220.4	16.4
3.	245.6	203.6	17.1
4.	275	230	16.4
5.	255.5	2155	15.7
6.	284	238	16.2
MEAN	-	-	16.4

Table 3: Fuel consumption rate of three makes of tractors at an idle operation.

	Fuel consumed (L/30min)			Fuel consumed (L/h)		
	FIAT - 666	MF - 185	STEYR - 80 75	FIAT - 666	MF - 185	STEYR - 8075
	0.5	0.55	2.65	1.0	1.10	5.30
	0.4	0.60	2.75	0.8	1.20	5.50
	0.4	0.60	2.73	0.8	1.20	5.46
Mean	0.433	0.593	2.71	0.867	1.1671	5.42

Table 4: Fuel consumption of Discplough – using fiat 666

(field operation)

REPLI-CATION	SPEED (RM/H	WIDTH OF CUT (cm)	DEPTH OF CUT (cm)	FUEL CONSUMED (l/h)	FUEL REQUIRED (l/ha)
R_1	4.31	81.2	17.7	4.46	-
R_2	3.78	90.7	19.5	19.13	-
R_3	4.24	90.2	18.5	10.24	-
R_4	4.05	88.4	17.7	5.58	-
R_5	3.95	84.8	17.0	5.45	-
R_6	3.94	89.4	17.5	6.79	-
Mean	4.05	87.5	18.02	6.94	19.64

4.1 DISCUSSION

Table 3 shows the fuel consumption of the tractors on idle operation, the: fiat – 666 tractor consumed 0.867 l/h, MF - 185 tractor consumed 1.167 l/h, and steyr – 8075 tractor consumed 5. 42 l/h diesel fuel. These show that steyr – 8075 tractor has highest fuel consumption when compared with others; and the fuel consumed by fiat –666 was so minimal. It seems that MF – 185 and Fiat – 666 are more fuel economic than steyr – 8075 tractor.

Table 4 shows the fuel consumption of Fiat – 666 tractor operating with on MF – mounted, 3 – bottom disc plough on soft soil of 16.4 per cent moisture content. The disc plough with 87.5cm width of cut and 18.02 cm depth of cut , operating at a speed of 4.05 km/h consumed 6. 94 l/h diesel fuel. From the table, when comparing R_1 and R_2 values it seems that increase in depth and width of out results in more fuel consumed by the tractor. At R_2 and R_3 with the tractor operating speed of 3. 78km /h and 4.24 km/h, fuel consumption was 9.13 l/h and 10.24 l/h of diesel fuel respectfully.

Also, at R_1 and R_3 at approximately constant tractor speed the fuel consumed at 81.2cm width and 17.7cm depth of cut was 4.46 l/h, while the fuel consumed at 90.2cm width of cut and 18.5cm depth of cut was 10.24 l/h. For R5 and R6 with approximately constant speed and depth of cut fuel consumed at 84.8cm width of cut was 5.45 l/h, while that consumed at 89.4cm width of cut was 6.79 l/h. Finally, the required fuel to operate one hectare of land was found to be 19.64 l/ha.

From the graph, figs. 1-3 which were plotted from the experimental results obtained from the ploughing operating at full load and variable speed, Fig 1 shows that, the economical speed range for the tractor to successfully operate with plough is between

4 – 4. 5 km/h of the full speed. It shows that any speed below or above those speeds will cause increase in fuel consumption. Fig. 2- 3, show support the fact that, fuel consumption by the tractor increase proportionally as the depth and width of cut increase. Also, apart from the fact that when engine is idling at low light load or at full load its fuel consumption is high.

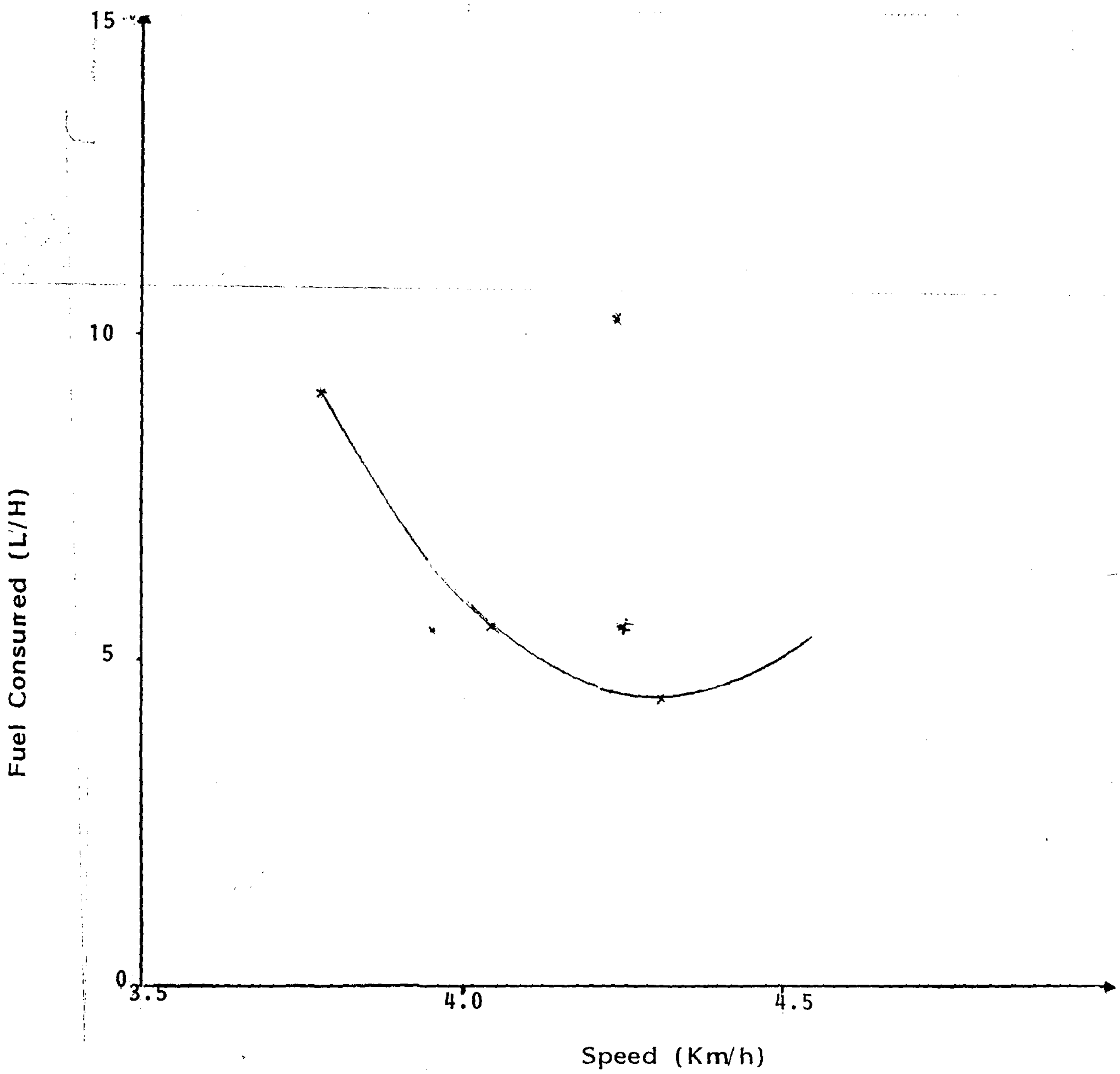


Fig. 1 Effect of Speed on fuel consumption

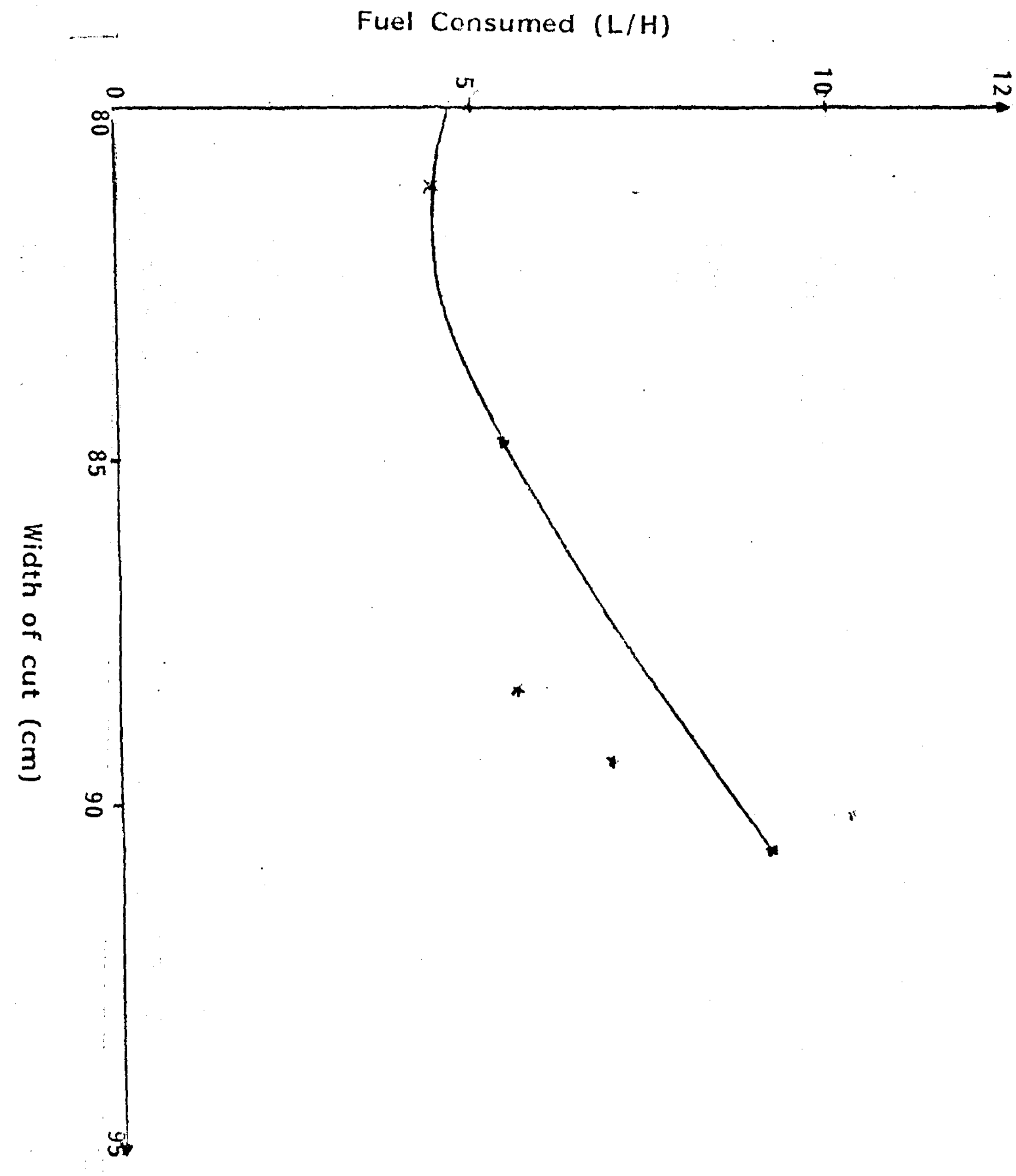
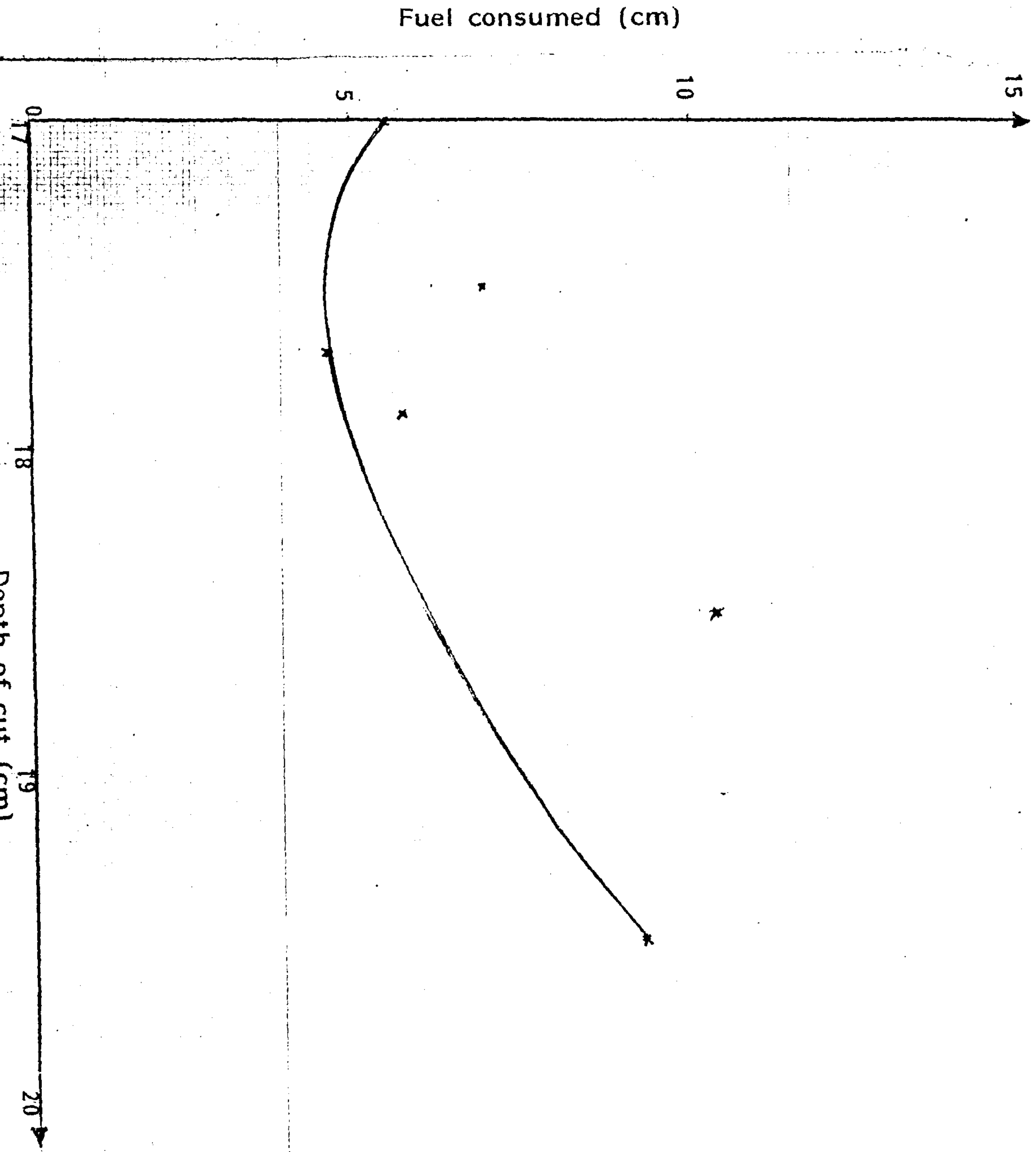


Fig. 2 Effect of width of cut on fuel consumption



Effect of depth of cut on fuel consumption

CHAPTER FIVE

5.0. CONCLUSION

From the results obtained in this work, indicates that Fiat - 666 tractor was considered has the most fuel economic on idle operation and the higher value of fuel consumed by Steyr – 8075 tractor was suggested to the faulty of the fuel system despite the facts of the different fuel consumption rate of the different engine type model and design. And the speed of operation, width of cut and depth of cut during the field operation (ploughing) have pronounced effects on fuel consumption by the tractors, showed that as these variable factors increased fuel consumption also increased.

Hence, operating the tractors and disc plough at good working condition of the systems, moderate speed, width of cut, depth of cut and accurate alignment of the disc plough have better advantage on fuel consumption by the tractors.

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APPENDIX

1. **Determination of Fuel Consumption of Discplough - using Fiat 666 (Field Operation)**

Total time spent = 12.93 min ≡ 0.2155hr

(i) Speed (km/h) = $\frac{\text{Length of plough (m)}}{1000} \times \frac{60}{\text{Time taken (min)}}$

$R_1 = \frac{145}{1000} \times \frac{60}{2.02} = 4.31$ (km/h)

$R_2 = 0.145 \times \frac{60}{2.30} = 3.75$ (km/h)

$R_3 = 0.145 \times \frac{60}{2.05} = 4.24$ (km/h)

$R_4 = 0.145 \times \frac{60}{2.15} = 4.05$ (km/h)

$R_5 = 0.145 \times \frac{60}{2.20} = 3.95$ (km/h)

$R_6 = 0.145 \times \frac{60}{2.21} = 3.94$ (km/h)

(ii) Fuel consumed (l/h) = $\frac{\text{litre}}{\text{Time taken (min)}} \times 60$

$R_1 = \frac{0.15}{2.30} \times 60 = 4.46$ (l/h)

$R_2 = \frac{0.35}{2.05} \times 60 = 9.13$ (l/h)

$R_3 = \frac{0.35}{2.05} \times 60 = 10.24$ (l/h)

$R_4 = \frac{0.2}{2.15} \times 60 = 5.45$ (l/h)

$R_5 = \frac{0.35}{2.20} \times 60 = 5.45$ (l/h)

$R_6 = \frac{0.25}{2.21} \times 60 = 6.79$ (l/h)

(iii) Fuel required (l/ha) = Mean fuel consumed (l/h) x Actual field capacity in (h/ha)

Area plough = width x length

= $(5.25 \times 145) m^2$

= 761.25m2 ≡ 0.076125 ha

Effective/Actual field capacity (EFC) = $\frac{\text{Area plough in (ha)}}{\text{Total time taken (h)}}$

EFC = $\frac{0.076125}{0.2155}$

= 0.353 (ha/h)

But, 0.353 (ha/h) = 2.83 (h/ha).

∴ Required fuel (l/ha) = 6.94 (l/h) x 2.83 (h/ha)

= 19.64 l/ha

2. **Determination of Soil Moisture Content of Test Soil**

Moisture contract = $\frac{\text{weight of wet soil} - \text{weight of dry soil}}{\text{weight of wet soil}}$

Soil sample 1 = $\frac{240.5 - 200.5}{240.5} \times 100$ = 16.6%

" 2 = $\frac{263.4 - 220.4}{263.4} \times 100$ = 16.4%

" 3 = $\frac{2456. - 203.6}{245.6} \times 100$ = 17.1%

Soil sample 4 = $\frac{275 - 230}{275} \times 100$ = 16.4%

" 5 = $\frac{255.5 - 215.5}{}$ x 100 = 15.7%

255.5

„ 6 = $\frac{284 - 238}{284} \times 100 = 16.2\%$

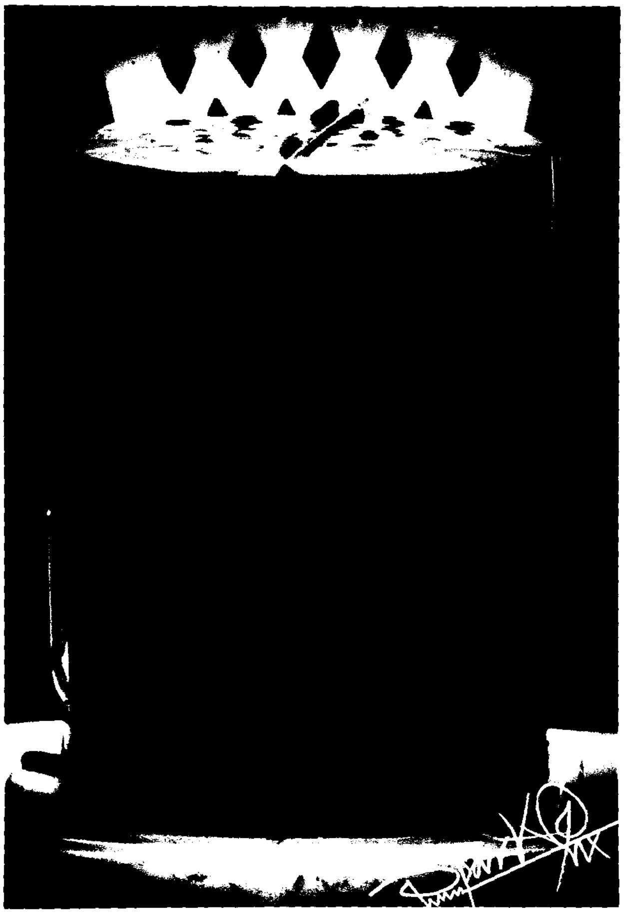

Plate 1: Fuel Flow Meter.