Research Article

Journal of Agronomy research ISSN: 2639-3166

Freely Available Online

Field Performance Evaluation of a Combined Cultivator (Rigid tine - Furrow Reformer – Fertilizer Applicator) at Kenana Sugar Company

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Keywords:

Sugar cane; cultivation, furrow-reforming and Fertilizer placement, field productivity

Received: Jun 16, 2021

Accepted: Oct 15, 2021

Published:

Editor:

Giorgio Masoero, Italy

DOI: 10.14302/issn.2639-3166.jar-21-3872

Abstract

Sugar cane production requires a number of operations to be carried out in the field through number of implements and machines. Therefore, time consuming and required large amount of energy. A combined field cultivator was designed in Kenana agricultural implements factory (KAIF) to carry out at one time multi operations (cultivation, furrow-reforming and Fertilizer placement). This is to increase field productivity, reduce farm power and lower operation time and cost. The combined implement was evaluated in Kenana cultivation fields and compared with three individual implements, rigid tine cultivator, furrow-reformer and fertilizer applicator. The measured parameters were drawbar pull, power requirements, field capacity, fuel consumption and total time in the field. The results showed highly significant differences at 1% level between the different implements for the field capacity, fuel consumption and significant differences at 5% for the drawbar pull. A power requirement in (kW) for the combined cultivator was 77% of those individual implements. Total time per feddan to accomplish the required operations by the combined cultivator was 57% of that required by the individual implements. Fuel consumption was reduced to 57% when combined implement was used compared to that consumed by individual implements. It was concluded that the combined cultivator was effective in increasing field productivity and reducing power and cost of operation.

Introduction

Farm machinery management deals with the optimization of the equipment used for agricultural production. It is concerned with efficient selection, operation, maintenance, and replacement of machinery. Farm machinery selection is a fundamental in achieving the concept of sustainable agriculture, which becomes a global issue in agricultural sector development[1] .Proper management and selection of implement contributes greatly in reducing cost and difficulties in field operations, maximizes production and also protects the environment against pollution.

Sugar industry in Sudan, started in the sixties and reached its present size in the eighties. Sugar industry has a significant contribution to the national income and the economy of the country. Sugar cane in Sudan is now grown in the central clay plains and the expansion in this region depends in the suitable soil, availability of irrigation water and machinery. The production of sugar cane involves many operations from planting to harvesting. It is produced either by planting stalks of cane or by ratoon. [2] considered the following operations as common practices in sugar cane field; uprooting, by chisel, disc or shape ploughs, harrowing, with discs or tines to form a suitable seedbed. Then leveling and furrows made by furrowing bodies for planting seed cane. For planting, cane is usually placed in furrows and covered with soil. [3] recommended planting depth of 8 cm in sandy soils and found that depth was not so important in heavy cracking clay soils. To maximize cane yields, the distance between cane rows should be the smallest which allows cultivation with modern equipment[4]. Where the plant is about three months old, soil should be transferred from the inter-rows to the planting rows so that the plant gets better anchorage and resistance to lodging. This also helps prevent water logging at the base of stalks and improves irrigation efficiency, besides, the practice is necessary for mechanized harvesting operations[5].

The concept of combined implement was found to be of great importance to carry out more than one operation at the same time and to conserve energy and time and to save labour cost. Some pioneer studies were carried out to combine tillage implements with planting machines as a minimum tillage combined systems[6,7,8] found that combining tillage tools in two types of soils resulted in saving about 44-55% of the cost and 50-55% of the time. [9] described a combined chisel-planter as a minimum tillage implement, for reducing erosion. The minimum tillage system was developed by combining through successive practical in the area (a chisel plow, fertilizers applicator and seed drill with double disc furrow openers). It was classified as tillage – planting machine. The interest for minimum tillage or no tillage methods of seeding involve saving time and energy. He also concluded that the chisel –planter used 70% less fuel, and 49% less time per acre than conventional system. [10] stated that the combination of a rotary tiller and pneumatic seeder was found to be suitable for one-pass plow-seeding operation as a minimum tillage system for fuel and time saving. [6] stated that the ridger- planter as one pass operating machine, the conventional mechanical system of planting (separate ridger and planter) was nearly double that of combined ridger-planter and field capacity of the combination was approximately double that of the mechanical system and twelve times the manual, which allows times saving and expansion of the cultivable area.

Carried out an experiment to study the performance of a primary and secondary tillage implements combined into one machine and was evaluated in the field and compared with the individual implements, chisel and ridger for unit draft, power, slippage, fuel consumption and time.[11] The results showed that the combined implement reduced the unit draft by 26% compared to the individual implements work together. The power requirements and the total times were reduced by 49% and 47% respectively by the combined implement.

The main objective of the present study was to develop and evaluate a combined machine formed from three implements, rigid tine cultivator, furrow reformer and fertilizer applicator to increase field productively, reduce farm power and lower operational costs and time. Therefore, the specific objectives are: To evaluate the field performance of the combined machine compared to the individual implements. The parameters investigated and measured were field capacity and efficiency, fuel consumption and power requirement.

Materials and Methods

The experiment was carried out at Kenana cane fields (heavy clay soil). The soil is 15% sand, 22% silt, 63% clay (Kenana research department). Kenana Latitude is 13°8'16"N and Long 33°0'31"E.

An experimental plot consalmaisting of four treatments and three replicates was laid out in randomized complete block design (RCBD). The treatments consisted of four implements as shown in (Fig. 1).

Two Massey Ferguson tractors (MF440) were used for the experimental measurements. The specifications of the tractors are given in table (1).

The implements used in this study as shown in (Fig. 1 a,b and c) were rigid tine cultivator, furrow reformer, fertilizer applicator and the combined field cultivator which developed as a two row cultivator. The specifications of these implements are shown in table (2). The size of the plots was 100 m×3 m. The plots were separated by 3 m wide buffer strips and there was 6 m gap between 2 plots for the tractor. Other equipment such as Chain- bolts- stop watch- paper sheets- tape meter (50m) - steel rods- steel container (4 gallons) - measuring cylinder (1 lit.) and dynamometer (50_300 KN) were also used.

The cultivator consists of six rigid tynes, equipped with replaceable chisel points, staggered on a rugged tool bar in twos, for each furrow there were three tynes, two in the front row, and third in the second row, at the center of the two front tynes. The front tynes were to loosen the sides of the furrows and to provide grooves for placement of fertilizers. The center tynes were to loosen the middle of the furrows to provide more loose soil for coverage of fertilizers and reshaping of the ridges and furrows. The fertilizer applicator consists of fertilizer hoper, metering devices, and delivery tubes. There were two main hopers one for each row. Capacities of the compartment were 300kg of fertilizer.

The metering devices were tractor-PTO driven mechanism specially designed for the machine. Fertilizer displacement (flow) was controllable through the setting of the drive linkages. Delivery tubes attached to the outlets of the metering devices and clamped to the backs of the front times. The furrowing unit was a set of two moldboards, in addition to ridge and furrow reformation, furrowers were to cover fertilizer.

The combined field cultivator was developed as a two row cultivator, tractor mounted machine. It was designed to comprise functional components of a chisel cultivator, furrower and a fertilizer applicator. (The specifications of this machine is shown in table (3)

Measurements

Field Capacity and Efficiency Measurements

The time lost in the field such as turning, adjustment and change of gear was recorded and time used for real work also recorded. The theoretical, effective field capacity and field efficiency were calculated as follows

$$Effective\ field\ capacity\left(\frac{ha}{hr}\right) = \frac{Area\ of\ the\ plot\ (300m^2)\ x(1ha)}{Time\ needed\ to\ cover\ the\ plot\ (hr)\ x10000m^2}$$

$$Theoratical\ field\ capacity\left(\frac{ha}{hr}\right) = \frac{Average\ travelling\ speed\ \left(\frac{m}{sec}\right) x\ width\ of\ cut\ (m) x\ 1ha}{10000m^2\ x3600}$$

$$Field\ Efficiency\ (\%) = \frac{EFC\ (ha/hr)}{TFC\ (ha/hr)} \times 100$$

$$Field\ Efficiency\ (\%) = \frac{Productive\ time\ (hr)}{Total\ time\ in\ the\ field\ (hr)}\ x\ 100$$

Fuel Consumption Measurement

For measuring the fuel consumption of tractor, the fuel tank was filled up to neck of the fuel tank before and after the planting operation in each plot. The amount of refilling measured after the test was the fuel consumption for planting operation in each plot and it was expressed as liter per hour and calculated as follows:

Table 1. Specification of tractors used on experiments (MF 440)

Item	Description
Model	Perkins
No. of cylinders	7
HP	82(61.6KW)
Rev/m	2200
Injection	Direct
Capacity	1.4 lit
Aspiration	Natural
Steering	Hydrostatic
Max. engine torque	288NM
Weight	2665kg
Length	3.98m
Width	2.06m

Table 2. Specifications of Implements

Parameter	Specifications		
	Fertilizer applicator	Ridger	Rigid tyne
Type	Tractor mounted	Tractor mounted	Tractor mounted
Lifting	By Tractor hydraulic	By Tractor hydraulic	By Tractor hydraulic
Height	1550 mm	365mm	800mm
Length	1110mm	980mm	1200
Width	2480mm	1000mm	1800mm
Components	Mild steel frame, hoppers(4), transmission system.	Two wings v shape frame, cutting edges	Eight shanks, two raw u shape frame.

Table 3. Specification of combined Field cultivator

Parameter	Specification
Type	Mounted two raw
Lifting	By tractor hydraulic
Overall height	1460mm
Length	1665mm
Width	2480mm
Hoper capacity	400kg of Fertilizer
Components	Fertilizer applicator Rigid tine Ridger

Measurements

Draw Bar pull (Draft) Measurement

$$\text{The fuel consumption rate } (L/ha) = \frac{\text{Reading of cylinder } (ml)/1000}{\text{Plot area } (m)/10000}$$

$$\text{The fuel consumption rate } (L/hr) = \frac{\text{Reading of cylinder } (ml)/1000}{\text{The required time to cover the plot } (hr)}$$

Measurement of Each Implement Draw Bar Pull (Draft) was Done as Follows

- The auxiliary tractor (MF) and the tested tractor (MF) were linked together through the dynamometer using steel chain.
- The auxiliary tractor was first used to pull the tested tractor alone.
- The reading of the dynamometer was recorded
- The tested tractor then loaded with the implement operated at constant depth controlled with manual hydraulic lever of the tractor
- The reading was repeated and taken the average

Implement draft was calculated as follows

Draw Bar Power Calculation

The power exerted by the tractor on the im-

$$\text{Implement draft } (KN) = \text{pull of tested tractor with implement } (KN) - \text{Pull of the same tractor only} (KN)$$

plement was calculated using the following equation:

$$Dbp = \frac{D \times S}{3.6}$$

Dbp (KW) = Draw bar power

D = Implement draft (KN)

S = Forward speed (Km/hr)

Field Capacity and Efficiency Measurements

The time lost in the field such as turning, adjustment and change of gear was recorded and time used for real work also recorded. The theoretical, effective field capacity and field efficiency were calculated as follows

$$\text{Effective field capacity} \left(\frac{ha}{hr}\right) = \frac{\text{Area of the plot } (300m^2)\, x (1ha)}{\text{Time needed to cover the plot } (hr)\, x 10000m^2}$$

$$\text{Theoratical field capacity} \left(\frac{ha}{hr}\right) = \frac{\text{Average travelling speed} \left(\frac{m}{sec}\right) x \text{ width of cut } (m) x\, 1ha}{10000m^2\, x 3600}$$

$$\text{Field Efficiency } (\%) = \frac{EFC\ (ha/hr)}{TFC\ (ha/hr)} \times 100$$

$$\text{Field Efficiency } (\%) = \frac{\text{Productive time } (hr)}{\text{Total time in the field } (hr)} \times 100$$

Fuel Consumption Measurement

For measuring the fuel consumption of tractor, the fuel tank was filled up to neck of the fuel tank before and after the planting operation in each plot. The amount of refilling measured after the test was the fuel consumption for planting operation in each plot and it

$$\text{The fuel consumption rate } (L/ha) = \frac{\text{Reading of cylinder } (ml)/1000}{\text{Plot area } (m)/10000}$$

$$\text{The fuel consumption rate } (L/hr) = \frac{\text{Reading of cylinder } (ml)/1000}{\text{The required time to cover the plot } (hr)}$$

was expressed as liter per hour and calculated as follows

Draft &Power Requirements

Table (4) shows a summary for performance of the individual implements and combined machine in the experimental fields. It is clear that the combined implement recorded less value of unit draft (3.02 KN/m), than Ridger (5.3 KN/m) and Rigid tine (4.5 KN/m), but the Fertilizer applicator recorded the lowest value of unit draft (0.17 KN/m).

Table (4) also shows that the combined machine recorded (12.51 KW) power requirement which is higher than that of ridger, fertilizer applicator and rigid tine together which recorded (5.6 KW+ 0.80 kW+ 9.8 KW= 16.2 kW). The higher power required the combined implement compared to the individual implements may

Table 4. Average field capacity, fuel consumption, draw bar pull, draw bar power requirement and unit draft

Implement	FC(Fad/hr)	Fuel C (lit/Fed)	Draw bar pull (KN)	D b power (KW)	U d (KN/m)
Combined	2.57	2.41	7.51	12.51	3.02
Ridger	2.54	2.05	3.40	5.6	5.3
Fertilizer App.	8.43	0.45	0.50	0.83	0.17
Rigid tine	2.5	1.75	5.90	9.8	4.5

FC = Field Capacity, Fuel C = Fuel Consumption, D b = Draw Bar, U d = Unit Draft

Table 5. Anova Table for different parameters

Parameters	F value		
	f-cal.	F-tab.	
		5%	1%
Field capacity	**44.5	8.62	26.5
Fuel consumption	**1584	8.62	26.5
Drawbar pull	*15.9	8.62	26.5

Table 6. Total time of different Implements

Implement	**Total time (h/feddan)**
Combined machine	0.39
Ridger	0.40
Fertilizer applicator	0.11
Rigid tyne	0.40

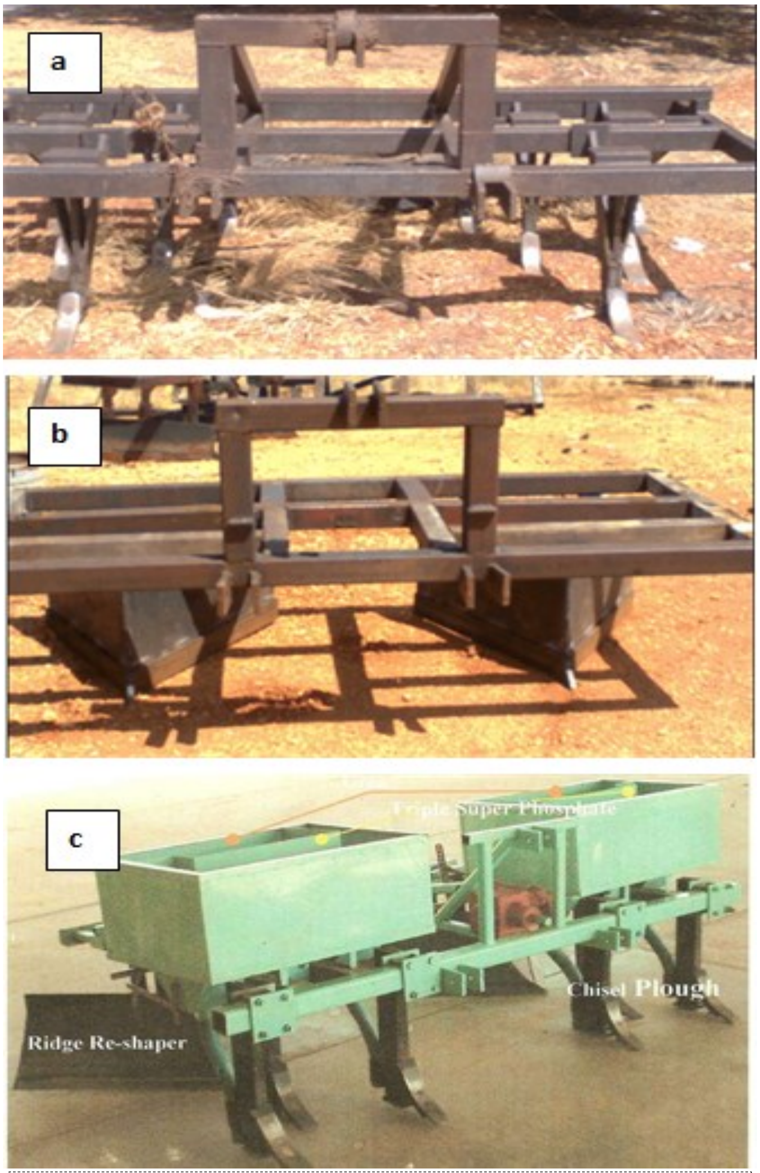

Figure 1. The implements used in the experiment **a.** Rigid tyne cultivator, **b.** Furrow reformer (Ridger); **c.** Combined machine

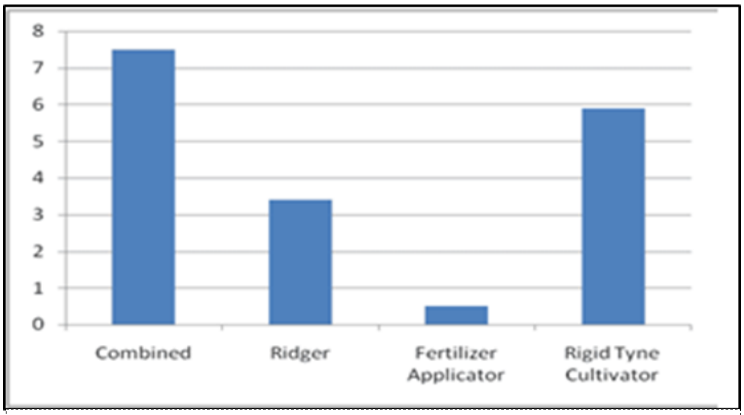

Figure 2. power requirement as affected by implement type

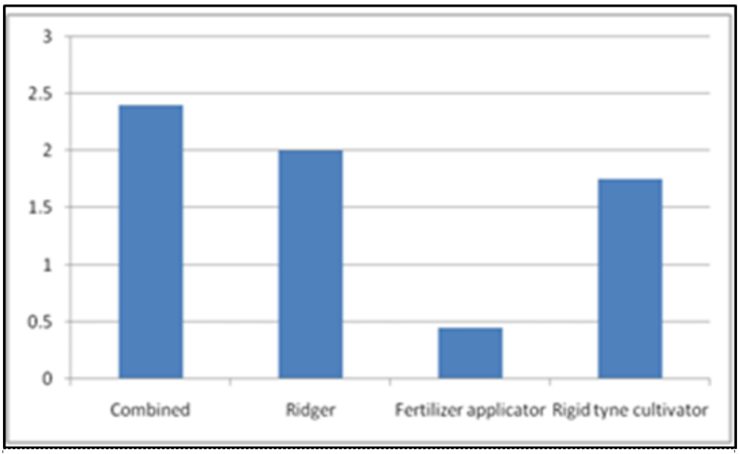

Figure 3. Fuel consumption (Lit/ fed) as affected by implement type

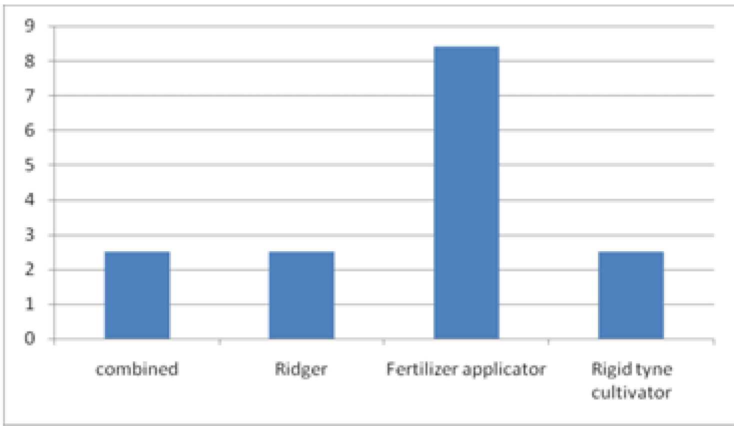

Figure 4. Field capacity as affected by implement type

be due to higher draft force exerted by the combined implement. [12] reported that draw bar power was increased as implement draft increased.

Adding the power required for ridger, rigid tine and fertilizer applicator all together and comparing them with power required by the combined implement showed that the power required was less by 3.7 KW, this saved about (23%) of power when using combined implement. This is in line with Paterno, (1994)[6].

Statistical analysis shows significant differences between treatments at 5% level, (Table 5). Figure (2) shows the power requirement for combined machine and the other three implements.

Fuel Consumption

From table (4), it is clear that the fuel consumption of the three individual implements when added together and compared with fuel consumption of the combined machine which carry out the three operations in one bath, it appear that the combined machine save about (57%) of fuel, which is above the rate mentioned[10].

Statistical analysis shows highly significant differences between treatments at 1% level (Table 5)

Field Capacity

Field capacity (fed/h) shown in table (4), it appear that the combined machine operates (2.57 fed/h), while the ridger, fertilizer applicator and rigid tyne operate (2.54, 8.43, 2.5 fed/h) respectively. So the combined machine in one path did the three operations done by the three implements and almost in the same time.

Statistical analysis shows highly significant differences between treatments at 1% level, (Table 5). Figure (4) shows field capacity for the combined machine and the three individual implements.

Conclusions

The Following Conclusion may be Drawn from the Present Study

The combined machine compared with individual implements (ridger, fertilizer app., rigid tine) was found reduced the power required by (23%), total time by (57%), fuel consumption by (57%) and operate the same area done by the three implements together in the same period of time.

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