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MINIMIZE ENERGY AND COSTS REQUIREMENT OF WEEDING AND FERTILIZING PROCESS FOR FIBER CROPS IN SMALL FARMS

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Abstract

The experimental work was carried out through agricultural summer season of 2014 at the experimental farm of Gemmiza Research Station, Gharbiya governorate to minimize energy and costs in weeding and fertilizing processes for fiber crops (Kenaf and Roselle) in small farms. The manufactured multipurpose unit performance was studied as a function of change in machine forward speed (2.2, 2.8, 3.4 and 4 Km/h) fertilizing rates (30,45 and 60 Kg.N.fed^{-1}),and constant soil moisture content was 20%(d.b) in average. Performance of the manufactured machine was evaluated in terms of fuel consumption, power and energy requirements, effective field capacity, theoretical field capacity, field efficiency, and operational costs as a machine measurements .The experiment results reveled that the manufactured machine decreased energy and increased effective field capacity and efficiency under the following conditions: -machine forward speed 2.2Kmlh. -moisture content average 20%.

Key words: *fertilization, fiber crops, minimize energy, small farms weeding*

INTRODUCTION

Fiber crops like Kenaf *(Hibiscus cannabinus)* and Roselle. *(Hibiscus Sabdariffa)* are of the most economic crops in the world. It produces a good fiber which used for making many agricultural and industrial applications like paper pulp, thermoplastics, fishing nets, ropes and doormats. Oil produced by the plants is used for first-class cooking oil and margarine production. These two species belong to the family Malvaceae. Chemical fertilizer application for fiber crops is very important while Nitrogen is essential for cell enlargement and deviation of cell at faster rate. Phosphor helps in paper root development. Potassium important in inducing drought tolerance in crops. [2]**.**physical properties of Roselle seed cultivated in Egypt in clinding (length, width, thickness moisture content ,mass of 1000-Kernels ,volume , percent of sphericity, geometric diameter, arithmetic diameter and bulk density).He found that (length, width and thickness of the seeds was (5.40, 3.02, 11.39, and 4.10) mm, respectively . He showed that 1000 seed mass was 40g respectively; the sphericity was 71.61.The bulk density was .86 Kgm^{-3} respectively. [4] developed a 5.4 kW diesel engine operated power weeder for weeding and intercultural in sugarcane crop. The machine was capable of weeding 1 ha/day. Sufficient soil mulch was produced for better crop growth. The effective field capacity and weeding efficiency was observed to be 0.082 ha/h and 96% respectively [5]. Kenaf fertilization was applied in two doses. The first was applied at sowing as basal dressing with 50 kg N ha^{-1}, 50 kg P ha^{-1} and 50 kg K ha^{-1} in all plots, except N0 plots in which only P and K fertilization was applied. The second dose was applied on the onset vegetative phase, when plant height was approximately at50 cm [6] evaluated a self-propelled, engine operated power weeder, which has a diesel engine of 3.8 hp (3600 rpm), as a power source. The weeder has L-shaped blades. This weeder was found to be suitable for weeding in wider row crops like maize, cotton, sugarcane etc. The moisture content of the soil at the time of evaluation was 17-18 %. The depth of operation ranged from 4-7 cm (avg. 6.8 cm). The machine was operated at an average forward speed of 1.64 km/h. The weeding efficiency of 88% was obtained with the machine. At the time of weeding minor injuries to cotton plants (1.84%) were observed but these injuries are recoverable type [7] Weeding, thinning and hoeing are three major intercultural operations attempted in fiber crops. Among these weeding takes nearly 25-30% of the total cost of production. If the weeding is not done at proper time, whole crop is adversely affected. The Roselle plant have a greatest medical important it is useful in arteriosclerosis. Reported to be antiseptic, astringent, cholagogue, demulcent, digestive, emollient, purgative, refrigerant, stomachic, and tonic, Roselle is a folk remedy for abscesses, bilious conditions, cancer, cough, debility, dyspepsia, dysuria, fever, hangover, heart ailments, hypertension, neurosis, scurvy, and strangury.

MATERIALS AND METHODS

Experiment was carried out through Summer season of 2014 at the experimental farm Research Station, Gemmiza; Gharbiya governorate Egypt .to Manufacturing weeding and fertilizing unit mounted on walking tractor to suit small farms .

Optimize some different parameters affecting the performance of double acting unit .And minimize energy and cost requirements.

Table 1. Some soil characteristics of the experimental soil.

Soil texture	Bulk Density gm|cm^3	Porosity	pH	Ec dsm-1	NPK, p.p.m		
					N	**P**	**K**
Clay	**1.17**	**55.849**	**7.5**	**2.1**	**59**	**10.1**	**273**

1.Materials

1.1. Fiber crops

Tow types of fiber crops were used in this study, Roselle (*Hibiscuses Sabdariffa*) variety Egyptian Roselle and Kenaf(*Hibiscus Cannabinus*) variety Giza3.

Table 2. Physical properties of Kenaf and Roselle seeds.

Physical properties	Kenaf seeds	Roselle seeds
Length, mm	4.12	4.24
Width, mm	2.58	3
Thickness, mm	1.44	1.06
Volume, mm^3	15.306	13.48
Mass of 1,000 seeds, g	20	21.5
Bulk density mg/mm^3	1.3	1.59

1.2.The power source. Four strokes- diesel engine Walking tractor-SH151-1 of(11.03kW) was used as a power source.

1.3 Dual purpose unit.

A local manufactured combined cultivating and fertilizing unit for small farms consists of the following parts as shown in fig 1.

(i)-Frame and wheels. The main fixed frame is made of iron sheet steel. with dimensions of 150 cm length,36 cm width and 18 cm height. The frame includes elements to fix the weeding and fertilizing unit, also a hanged joint was constructed to attached the manufactured machine with the walking tractor. It was carried by tow ground wheels with 70cm diameter.

(ii)- Weeding unit consists of three beams and three shares every single share was fixed in one beam with the ability of changing the distance between beams and the depth of share in the soil.

(iii)- Fertilizing unit consists of two fertilizer hopper feed mechanism, fertilizing tubes, furrow openers and machine wheels as shown in fig 2.

(iv)-Feeding mechanism consists of three parts arranged from up to down.

1-Upper disc: it has a semicircular peripheral aperture with a curved shape, the fertilizer follow from it to the following disc.2. Circular disc: it has eight cells with a trapezoidal shape 3. Down disc

(v)-Transmission system: the motion was transmitted from the machine wheel to the fertilizing unit through out three groups of tooth wheels; each group was six toothed wheels (14, 16,18,21,24 and 28 teeth) and was fixed together with one piece which could be used to change the speed by putting the transmission chain between group and another according to permitted speed.

(vi)-Furrow fertilizers openers: two furrow openers were fixed in two beams and later fixed in the main frame to facilitate the changing of distance between beam and depth of furrow fertilizer opener .

(vii)-Covering device: the covering device was composed of two ground wheels.

2.Methods

The experimental area was about 720 m^2 which was divided into two equal plots (360 m^2) .The first plot was cultivated with Kenaf (*Hibiscuss cannabinus*) crop ,Varity Giza3

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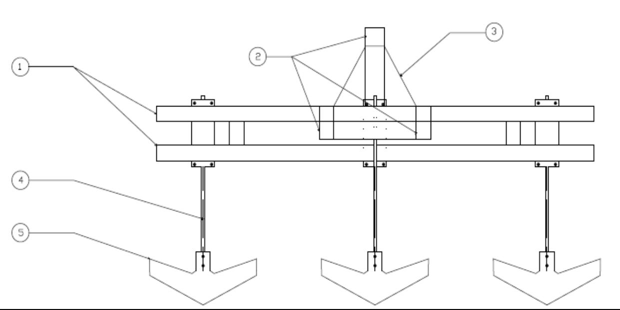
with row spacing 60 cm and distance between seeds in the same row 10 cm. while the second plot was cultivated with Roselle (*Hibiscus Sabdariffa)* crop, Varity Egyptian Roselle with row spacing 60 cm and distance between seeds in the same row 10 cm.

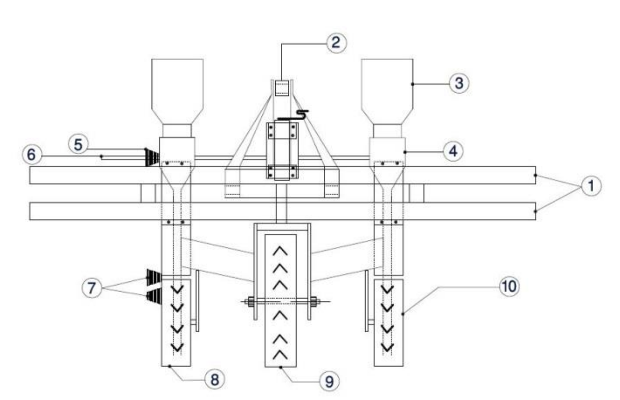
2.1. Experimental condition.

Field experiment was carried out to find the effect of four different parameters on the manufactured machine performance mainly:



No.	Parts names.
1	Main frame
2	Triangle hitch
3	Three points hitch
4	Beam
5	Weeding share

Fig . 1. The manufactured weeding unit**.**



No.	Part name .	No.	Part name .
1	Main frame	6	Transmission connect shaft.
2	Hitch point	7	Transmission system
3	Fertilizer hopper	8	Ground wheel to transmission unit
4	Feeding unit	9	Drive wheel
5	Group of tooth wheels	10	Ground wheel for machine balance

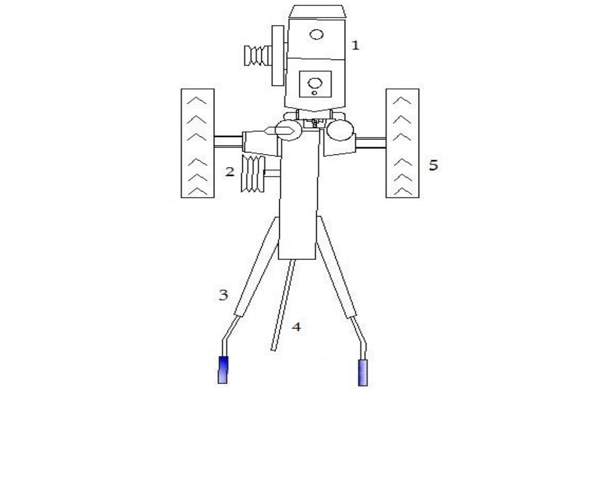
Fig. 2. The manufactured fertilizing unit.

1.Four different machine forward speeds (2.2, 2.8, 3.4 and 4 Km/h).

2.Three fertilizing rates (30, 45, and 60 Kg.N.fed^{-1}).

3.Three different plant population (20, 30, and 40 plant/m2).

4.Tow types of fiber crops Roselle and Kenaf plant.



No.	Parts names.
1	Engine
2	Pully
3	Driving hand
4	Changing speeds hand
5	Ground wheels

Fig. 3. The walking tractor machine

2.2. Measurements and determinations.

-Fuel consumption

$$\text{Fuel consumption} = \frac{\text{Fuel consumption, ml.}}{\text{Time , sec.}} \times 3.6, \text{ L/h}$$

-Field efficiency

The theoretical field capacity was calculated by using the following: formula:

$$Tfc = \frac{V \times W}{4.2} \text{ fed/h.}$$

Where: Tfc = Theoretical field capacity, fed, V = Average implement forward speeds, km/h; and W = The working width of implement, m

The Effective field capacity (Efc) was determined as follows:

$$Efc = \frac{1}{T}, \text{ fed/h}$$

Where: Efc = effective field capacity, fed/h, and T = The total time.

Field efficiency is the ratio of effective field capacity to theoretical field capacity and it gives an indication of the time lost in field and the failure to utilize the full working width of the machine. The field efficiency (ηf) was calculated by using the following formula:

$$\eta f = \frac{Efc}{Tfc} \times 100, \%$$

Where: ηf = Field efficiency, %, Efc = Effective field capacity, fed/h, and Tfc = Theoretical field capacity, fed/h.

***-Power requirements*:** the required power was calculated by using the following formula: [3]

$$EP = Fc \times (\frac{1}{3600})\, \rho_f \times L.C.V \times 427 \times \frac{1}{75} \times \frac{1}{1.36}\, \eta th \times \eta m, (kW)$$

Where:Fc= Fuel consumption, l/h, ρ_f = Density of the fuel (0.73kg/l for gasoline fuel), L.C.V. = Lower calorific value of fuel (11030 k cal /kg for gasoline fuel), 427 = Thermo – mechanical equivalent, kg.m/k cal, ηth = Thermal efficiency of engine (35% for diesel engine),and ηm =Mechanical efficiency of engine (80% for diesel engine).

***-Energy requirements*:** The energy requirements was calculated as follows:

$$\text{Energy requirements, kW.h / fed.} = \frac{\text{Required power, kW}}{\text{Effective field capacity, fed / h}}$$

- Operational cost:

The operating cost required for the fertilizing operation was estimated using **[1]** as the following:

$$C = \frac{P}{h}\left(\frac{1}{a} + \frac{i}{2} + t + r\right) + \left(0.9 W.S.F\right) + \frac{m}{144}$$

Where:
C = Hourly cost, L.E./h.
P = Price of machine, L.E.
a = Life expectancy of the machine, h.
I = Interest rate/year.
r = Repairs and maintenance ratio.
T = Taxes, over heads ratio.
0.9 = Factor accounting for lubrications.
W = Engine power, hp.
S = Specific fuel consumption, *l*/hp.h.
F = Fuel price, L.E./*l*.
m = Monthly average wage, L.E.
144 = Reasonable estimation of monthly working hours.

RESULTS AND DISCUSSIONS

The discussion will cover the obtained results under the following heads.

1.The impact of forward speed on fuel consumption.

it is obvious that using traditional method for weeding and fertilizing, increased the fuel consumption from 5.2 L/h to 8.6 L/h by increasing the forward speed from 2.2 km/h to 4 km/h. While under using one pass method for fertilizing and weeding in one process, the fuel consumption was 3 L/h with the forward speed 2.2 km/h and increased with increasing forward speed reaching a maximum of 5.5 L/h with 4 km/h forward speed. The results therefore demonstrated that individual operations saved fuel consumption by 42.3, 44.67, 37, and 36% with forward speed of 2.2, 2.8, 3.4 and 4 km/h, respectively. Linear regression analysis was run to derive equations to predict fuel consumption at different forward speed during fertilization and weeding treatments and the following equations represent the relationship.

Two pass: y = 1.8833x + 1.0867 R^2 = 0.99
One pass: y = 1.3833x - 0.4133 R^2 = 0.99

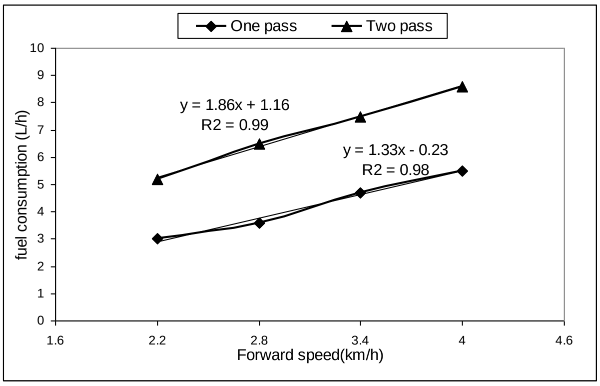


Fig 4. Relationship between forward speed and fuel consumption under the weeding and fertilizing treatments.

2.The impact of forward speed on required power.

Fig. 5 shows the relationship between forward speed and Engine Power under the different weeding and fertilizing treatments**.** It was observed that using two pass method, the total engine power recorded 13.8 kW/h with 2.2 Km/h and increased to 18.1kW/h with 4 km/h. While by using one pass method the required power was 7.5 kW/h unit with the forward speed 2.2Km/h, and recorded the highest value 11.2 kW/h with 4 Km/h forward speed. It was obvious that one pass method saved engine power by 42.65%, 44.8%,41.97% and

38.58% with forward speed 2.2 ,2.8, 3.4,and 4 km/h respectively. Linear regression analysis was performed to device equations to predict engine power at different forward speed during fertilization and weeding treatments and the following equation represented the relationship.

Two pass: $y = 2.43x + 8.40$ $R^2 = 0.96$
one pass: $y= 2.016x + 2.97$ $R^2 = 0.96$

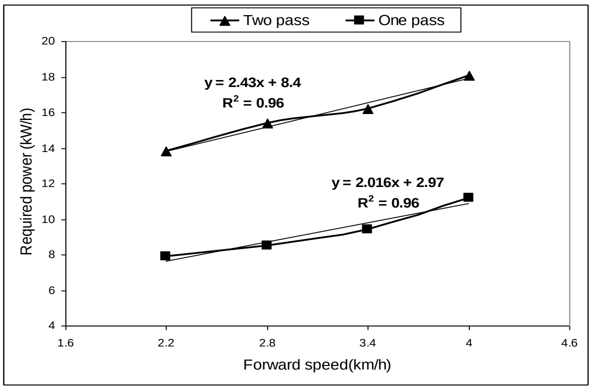


Fig. 5. Relationship between forward speed and Engine Power under the different weeding and fertilizing treatments

3.The impact of forward speed on Energy requirements.

Fig. 6 shows the relationship between forward speed and Energy required under the different weeding and fertilizing treatments**.** It was It was observed that using the traditional method, tow pass, increased the total energy requirements from 15.12 to 20 kW/h/fed by increasing forward speed from 2.2 up to 4 Km/h. Meanwhile by using one pass method energy requirements was increased from 9 to 12.8 kW/h/fed with as a result of increasing the forward speed from 2.2 up to 4 Km/h. It was observed that one pass method saved energy requirements by 40.8%, 42.7%, 41.3% and 36% with forward speed 2.2, 2.8, 3.4,and 4 km/h respectively. Linear regression analysis was run to derive equations to predict energy required at different forward speed during fertilization and weeding treatments and the following equation represented the relationship.

One pass: $y = 0.0117x + 0.1028$ $R^2 = 0.99$
Two pass: $y = 0.0127x + 0.0467$ $R^2 = 0.99$

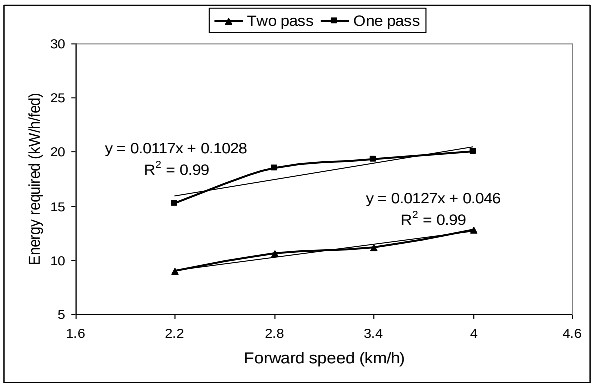


Fig. 6. Relationship between forward speed and Energy required under the weeding and fertilizing treatments.

4.The impact of forward speed on theoretical field capacity.

Fig. 7 shows the relationship between forward speed and theoretical field capacity under the different weeding and fertilizing treatments.it was clear that theoretical field capacity increased by forward speed increasing. using traditional method "two pass" theoretical field capacity was 1.4 fed/h with the forward speed 2.2km/h and reached to 2.7 fed/h with the forward speed 4 km/h . While using one pass method theoretical field capacity was 0.82 fed/h with the forward speed 2.2km/h and increased with the forward speed 4 km/h to reach to 1.6 fed/h. It was clear that one pass method saved theoretical field capacity with 41.4%, 42.1%, 37.5, and 37% with forward speed 2.2, 2.8, 3.4 and 4 Km/h, respectively.

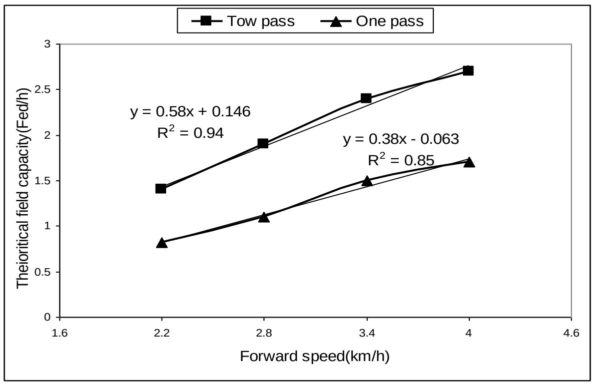


Fig. 7. Relationship between forward speed and Theoretical field capacity under the weeding and fertilizing treatments.

Linear regression analysis was run to derive equations to predict theoretical field capacity at different forward speed during fertilization and weeding treatments and the following equation represented the relationship.

Two pass: $y = 0.5867x + 0.146$ $R^2 = 0.94$
One pass: $y = 0.3817x - 0.036$ $R^2 = 0.85$

5.The impact of forward speed on effective field capacity.

Fig. 8 shows the relationship between forward speed and effective field capacity under the different weeding and fertilizing treatments obtained results show rise in the effective field capacity as the forward speed increased. using traditional method "tow pass" effective field capacity increased from 1.2 to 1.71 fed/h as the forward speed increased from 2.2 up to 4 km/h. while under using one pass method effective field capacity was 0.67 fed/h with the forward speed 2.2km/h and increased with the forward speed 2.8 Km/h to reach to 0.69 fed/h .and it was 0.84 fed/h with the forward speed 3.4 Km/h. The effective field capacity was recorded the highest value 0.98 fed/h with 4 Km/h forward speed. It was clear that one pass saved effective field capacity with 44.1%, 47.3%, 44.7, and 42.6% with forward speed 2.2, 2.8, 3.4 and 4 Km/h, respectively. Linear regression analysis was run to derive equations to predict effective field capacity at different forward speed during fertilization and weeding treatments and the following equation represented the relationship.

Two pass:- $y = 30.33x + 76.96$ $R^2 = 0.99$
One pass:- $y= 23.63x + 23.36$ $R^2 =0.99$

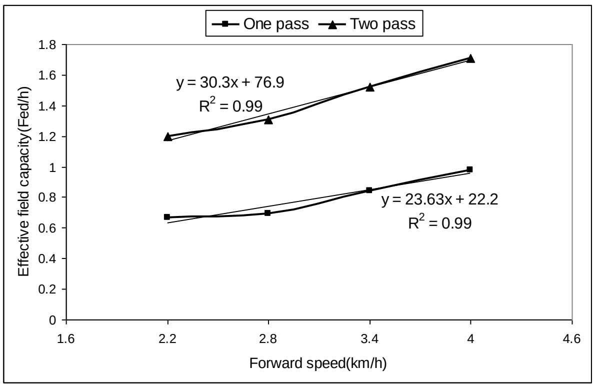


Fig. 8. Relationship between forward speed and Effective field capacity under the weeding and fertilizing treatments.

6.The impact of forward speed on field efficiency.

Fig. 9 shows the relationship between forward speed and field efficiency under the different weeding and fertilizing treatments. Obtained results show a remarkable drop in field efficiency as the forward speed increased. using traditional method "tow pass" the field efficiency at weeding process was decreased from 79.5 to 54.4% as the forward speed increased from 2.2 up to 4 Km/h forward speed. using fertilizing process only the field efficiency was decreased from 84 to 56.4% as the forward speed increased from 2.2 up to 4 Km/h. Meanwhile using one pass method the field efficiency was 81.7% with the forward speed 2.2Km/h and decreased to 73% with the forward speed 2.8 Km/h .it was 62% at forward speed 3.4 Km/h .The value of field efficiency was reached to the minimum value 51 at 4 Km/h forward speed. Linear regression analysis was run to derive equations to predict field efficiency at different forward speed during fertilization and weeding treatments and the following equations represent the relationship.

Weeding: $y = -13.68x + 110.29$ $R^2 = 0.98$
Fertilizing: $y = -15.18x + 117.94$ $R^2 = 0.99$
One pass: $y = -17.183x + 120.19$ $R^2 = 0.99$

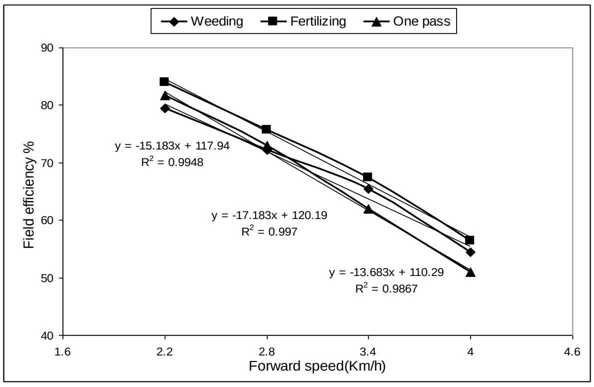


Fig. 9. Relationship between forward speed and Field efficiency under the weeding and fertilizing treatments.

7.The impact of forward speed on fertilizer losses.

Fig. 10 shows the relationship between forward speed Km/h and fertilizer losses. It was clear that the fertilizer losses increased as the forward speed increased. applying the nitrogen rate of 30Kg.N.fed-1 losses increased from 2.4 to 2.98 kg/fed as the forward speed increasing from 2.2 up to 4 Km/h. while applying the rate of 45Kg.N.fed-1 losses was increased from 3.54 to 4.94 kg/fed as the forward speed increased from 2.2 up to 4 Km/h forward speed. While applying the rate of 60Kg.N.fed-1 losses increased from 4.8 to 5.8 kg/fed by increasing the forward speed from 2.2 up to 4 Km/h. Linear regression analysis was run to derive equations to predict fertilizer losses different forward speed during fertilization and weeding treatments and the following equation represented the relationship.

60 kg.N.fed^{-1} : $y = 0.54x + 3.57$ $R^2 = 0.97$
45 kg.N.fed^{-1}: $y = 0.77x + 1.73$ $R^2 = 0.96$
30 kg.N.fed^{-1} : $y = 0.31x + 1.694$ $R^2 = 0.95$

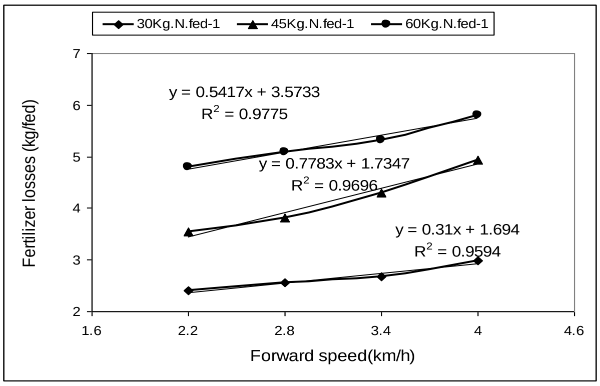


Fig. 10. Relationship between forward speed and Fertilizer losses ratio under the fertilizing treatments.

8.The impact of forward speed on weed index.

Fig. 11 shows the relationship between forward speed Km/h and weed index under different weeding treatments. It was obvious that by increasing forward speed from 2.2 Km/h up to 2.8 Km/h the weeding index was decreased from 86.12% to 83.8%. by increasing forward speed from3.4 Km/h to 4 Km/h the weeding index decreased from 80.9 % to 78.3% under the control (manual) treatment. Meanwhile using traditional method weeding index was decreased from 91.28% to 90.18% and from 88.78% to 87.74% by increasing the forward speed from 2.2 Km/h to 2.8 Km/h , and from 3.4 Km/h to 4 Km/h. on the other hand when using one pass method machine the weeding index was decreased from 90 to 88.64 by increasing forward speed from2.2 Km/h to2.8 Km/h and decreased from 86.7 6 to 84.87 with forward speed 3.4 Km/h, 4 Km/h respectively. Linear regression analysis was run to derive equations to predict weeding index at different forward speed during fertilization and weeding treatments and the following equation represented the relationship.

One pass: $y = -2.003x + 95.70$ $R^2 = 0.99$
traditional: $y = -2.878x + 96.49$ $R^2 = 0.99$
control : $y = -4.3933x + 95.89$ $R^2 = 0.99$

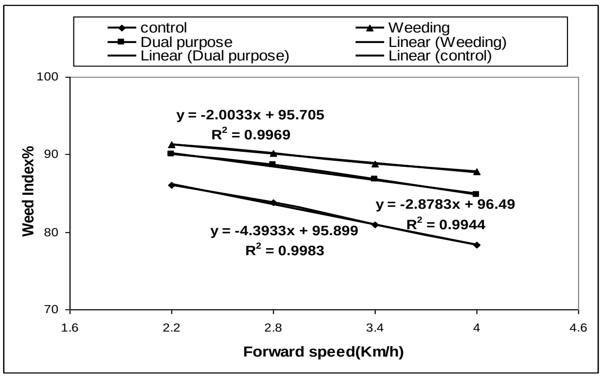


Fig. 11. Relationship between forward speed and Weed index.

9.Effect of machine forward speed on hourly cost.

Fig. 12 shows the effect of machine forward speed on hourly costs, it was clear that Data obtained showed that increasing the forward speed from 2.2 to 4 km/h increased the hourly cost from 155 to 159.8. L.E/Fed by applying the traditional method for weeding and fertilizing.

While by using one pass method for weeding and fertilizing together there was a remarkable drop in hourly costs it was increased from 77.5 to 80 L.E/Fed as the forward speed increased from 2.2 up to 4 km/h respectively.

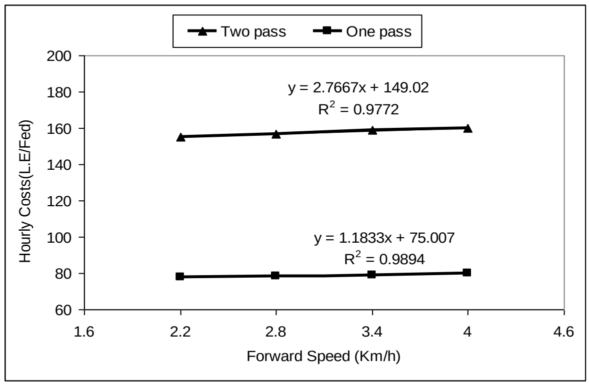


Fig. 12. Effect of machine forward speed on hourly cost under fertilizing and weeding treatments.

Linear regression analysis was run to derive equations to predict hourly costs at different forward speed during fertilization and weeding treatments and the following equation represented the relationship

Two pass: $y = 2.15x + 161.76$ $R^2 = 0.74$
One pass: $y = 1.466x + 74.85$ $R^2 = 0.27$

10.Effect of machine forward speed on operational cost.

Fig. 13 shows the effect of machine forward speed on operational costs, it was clear that, using the traditional method two pass for weeding and fertilizing the operational costs was decreased from 140 to 96.3 L.E/Fed as the forward speed increased from 2.2 to 4 Km/h.

While by using one pass method for weeding and fertilizing together the operational cost was decreased from 108 to 80.3 L.E/Fed as the forward speed increased from 2.2 to 4 Km/h. The decrease in operational costs by increasing forward speed is attributed to the increase of machine field capacity.

Linear regression analysis was run to derive equations to predict operational costs at different forward speed during fertilization and weeding treatments and the following equation represented the relationship

Two pass: $y = -20.93x + 185.05$ $R^2 = 0.98$
One pass: $y = -12.66x + 132.7$ $R^2 = 0.99$

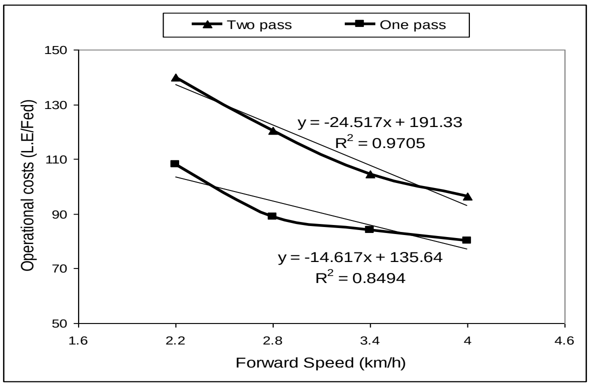


Fig. 13. Effect of machine forward speed on operational cost under different fertilizing and weeding treatments.

CONCLUSIONS

It was concluded that the fuel consumption, energy requirements, and operational costs were the optimum region during the weeding and fertilization at the forward speed of about 2.8 km/h.

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