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Manufacturing and Evaluating the Performance of an Automatic Unit for Trees Fertilizing

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ABSTRACT

Experiments were conducted to manufacture and evaluate an automatic mango tree fertilizing unit suitable for Egyptian conditions. The performance of the developed machine was studied according to the following criteria: Four different machine forward speeds (1.6, 2.0, 2.5 and 3.4 km/h), three different soil moisture contents (24.51, 29.67 and 36.88%) and three different fertilizing depths (8, 12 and 20cm). The performance of the manufactured machine was evaluated taking into account the following indicators: the amount of fertilizer needed for each tree, field capacity, field efficiency, specific energy requirement and operating costs. The fertilizer is applied when the unit's arm touches the tree and falls next to the tree at the specified fertilization depth. The optimum operating parameters for the developed mechanized tree fertilizing unit were found at machine forward speed of 2.0 km/h, fertilizing depth of 8 cm, soil moisture content of 36.88%, which gave a field capacity of 1.9 fed/h, fertilizing efficiency of 79.17%, field efficiency of 78.84 %, quantity of fertilizer 791.7 g/tree, specific energy consumption 2.61 kWh/fed and operating costs of this manufactured machine 153.3 LE/fed.

Key words: Fertilizer machines, mango trees, fertilizing depth, soil moisture content, field capacity, energy requirement, cost.

1. INTRODUCTION

Fertilization is one of the essential processes that promote healthy plant growth, as plants are able to obtain the necessary nutrients, they need to complete their life cycle, which leads to increased productivity and improved quality of fruits and leaves. How to reduce excessive unneeded fertilizing rates without adversely affecting plant nutritional requirements and lowering crop yields and plant product quality is one of the most promising issues for modern sustainable agriculture (**Chatzistathis *et al.*, 2021).** Young and mature fruit trees have a N use efficiency of less than 55%, according to (**Carranca *et al.*, 2018).** This can lead to N fertilizer losses, which raises environmental and economic problems. Numerous factors, including as cultivar, rootstock, climate, soil, pests, irrigation, and nutrition, influence the amount and quality of fruit., in addition to the nutrition of nitrogen, phosphorus, potassium, and magnesium. The use of biofertilizers in organic food production has been accompanied with the reduction of environmental pollution, increased N fixation and enhanced nutrients uptake, as well as stimulation of natural hormones biosynthesis and the production of antibiotics (**Subba-Rao *et al.*,1993).** Fruit trees, including stone fruits, are perennial plants, have deep roots, and remain for several decades in the same soil place. To achieve a high and stable yield, accompanied by good external and internal quality of the fruit, the reserves of nutrients in the soil fall from year to year and must be compensated by fertilization (**Milošević and Milošević,2020).** Horticultural productions, as an important part of agricultural activities, play an important and effective role in food security and community health. Fertilizing tree is one of the most important horticultural operations to improve the quality and quantity of horticultural production. Currently, the best way to fertilize trees is to dig holes around the trunks, these holes usually form on concentric circles around the tree, and their distance from the trunk of the tree depends on its species, root type, root growth pattern, and soil type. Their depth selection is based on the least damage to the roots and the maximum effectiveness of the fertilizer (**Heidarisoltanabadi *et al*,2024).** The prototype is a cost-effective and farmer-friendly automated fertilizing machine that enables fertilizer sprinkling in areas lacking in key macronutrients (potassium, phosphorous, and nitrogen). Farmers can afford the proposed device, which also eliminates manual labor, because its cost is one-seventh that of the current ways. Farmers in rural areas have less work to do since sprinklers cover specific sections of the field, automating fertilizing **(Oberoi *et al.*, 2017).** The most popular kinds of post-hole diggers are auger models, which include tractor-mounted and engine-powered models. A hydraulic-driven post-hole digger was used in confined places and can dig holes that are 15–20 cm broad and up to 50 cm deep. Unlike tractor and engine-powered models, the created machine uses a vertical force to screw down the auger at a very modest rotational speed. As the auger is raised, the dirt that has been compacted between its flights is removed from the hole Three different kinds of spiral augers with conical tips (two sizes of flight pitch), flange tips, and a cylindrical type were assessed in order to select the best auger for this machine. The findings indicated that the best spiral augers for this digger were those with conical tips, which used the least amount of energy and time. While larger auger pitches are more suited for sticky soils to prevent soil compaction between the auger's flights, smaller augers are advised for improved hole evacuation in hard and frictional soils **(Taki and Asadi, 2018)** The trials are divided into two phases. The first is laboratory calibration, which includes three variables: gate areas of 6.250, 12.500, 18.750, and 25.000 cm^2, hopper capacities of 25, 30, and 35 kg (head of 48, 56, and 63 cm), and discharge times of 60, 90, 120, and 150 seconds. The second is field calibration, which has fertilizer application rates of……. and forward speed parameters of 3.38, 4.37, 4.79, and 6.70 km/h. For the modified unit qualified to previously defined amounts of nitrogen in the soil, the fertilizer application rate was controlled in relation to the gate area. According to the data, a 3.125 cm^2 gate area at 1.33-1.86 m/s forward speeds is advised since the recommended amount of nitrogen fertilizer is around 150 kg/fed, to be applied in three doses (**El-Mageed *et al.*, 2015)** Compared to annual crops, the cost of production and returns for developing mango orchards are calculated differently. The goal is to look at the production costs and returns per acre over the course of a mango tree's life. The sampled respondent estimated net current worth was Rs. 155607.16 per acre, indicating that mango farming yields better returns. The benefit cost ratio, which came out to be Rs. 2.61, is also rather high, meaning that one rupee invested in mango cultivation would yield Rs. 2.61. According to these findings, planting mango orchards will yield significant profits for the nation in the form of foreign exchange revenues as well as for the farmers **(Bakhsh *et al.*, 2006)**. So, the objectives of this study are to: manufacture a local machine for fertilizing fruit trees, determine the most appropriate operating factors affecting the performance of the manufactured machine as well as the economic evaluation of the machine

2. MATERIALS AND METHODS

This study was conducted during the season 2019/2020 in the Department of Agricultural and Bio-systems Engineering Department, Faculty of Agriculture, Damietta University, to manufacture and establish a tree fertilizing unit under Egyptian conditions. Field experiments were conducted during the season 2023/2024 in the city of Zarqa, Damietta Governorate, to evaluate the performance of the developed tree fertilizing machine.

2.1. MATERIALS:

2.1.1. Soil properties:

Different samples were taken to determine mechanical analysis and some physical properties of the soil as shown in Table 1. The experiments were carried out in clay soil.

Table (1): Some properties of experimental soil:

Item	Value	Unit
Clay	55	%
Silt	30	%
Sand	15	%
Bulk density	1.5	kg/cm^3
Soil pH	6	–
Soil moisture content	14.7	%
Organic matter	1.05	%
Softness	medium softness	--
Soil texture type	Clay	--

2.1.2. Crop

Mango fruit trees were used under study as an important component of agroforestry systems in many parts of the world. The experiment was conducted on (2-3) years old mango trees. It is planted at a spacing of 5 m.

2.1.3. The fertilizer used:

The fertilizer (single superphosphate granular P_2O_5 12.5%) is used under the present study. Its granules are highly solid and completely homogeneous in diameter and shape, and are treated against hardening and clumping, which facilitates its mechanical spreading as shown in the following **Table (2)**. The amount of fertilizer required for each tree was determined according to the recommendations of the Egyptian Ministry of Agriculture.

Table (2): Physical properties of single superphosphate fertilizer:

Item	Value	Unit
(p_2)	12.5 - 15	%
(Ca O)	4.5	%
(S_2)	2.5	%
AV. Diameter	4	mm
The molar mass	283.9	g/mol
Density	2.39	g/cm^3
The melting point	613	K^o
The boiling point	633	K^o
Repose angle	45	degree
Coefficient of friction	0.5	--

2.1.4. Manufactured tree fertilizing machine:

The tree fertilizing machine was manufactured, developed and technically evaluated as illustrated in **Fig. (2.2)**. The tree fertilizing unit used in this study was manufactured and developed in a workshop in Zarqa city, Damietta Governorate, Egypt. Several considerations were taken into account during the manufacture of the tree fertilizing unit as follows: Construction and simplicity using locally available materials, the local tree fertilizing unit was developed and manufactured to be suitable for fertilizing different types of trees under Egyptian conditions and the materials were selected based on availability, durability, ease of manufacture and cost.

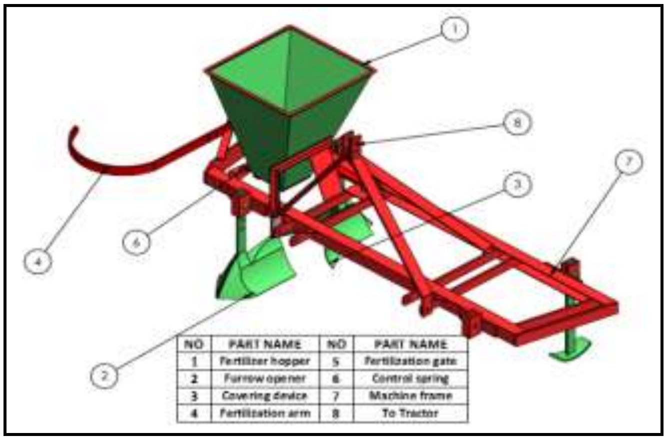

Fig. (2.2): 3D drawing of the tree fertilizing machine.

The main parts of the tree fertilizing unit are shown in the schematic diagram in **Fig. (2.3)** as follows:

1. Fertilizer hopper:

The hopper is manufactured from solid iron 1.5mm thick) in the form of a rectangular prism, the large hall has an area of 43×43cm and the small base has an area of 15×15cm and the height of the prism is 52cm. The sides of the hopper gradually slope to maintain a constant flow rate, as the fertilizer drop gate is located above the small base with a circular opening with a diameter of 5cm. The hopper is welded to the main body of the machine. The capacity of the hopper is 50kg of fertilizer, and the fertilizer drop process is controlled by opening the gate connected to the fertilizer arm.

2. Furrow opener:

The furrow opener is a longitudinal plow, consisting of two parts and installed on a vertical shaft of steel. It is like a duck leg, and there are a number of holes on its shaft to control its length**.**

3. Covering device:

The covering device consists of two incomplete rectangular wings made of iron, 1cm thick, tilted at an angle of 45° from the horizontal level, connected to a vertical column with a number of openings to control the depth.

4. Fertilizing arm:

It is an arm made of reinforced iron, with a bend at one end to deliver the required fertilizers to the trees, and the other end is connected to an arm with a fertilizing gate that has more than one opening to control the distance of the fertilizer falling from the tree**.**

5. Fertilizing gate:

A gate connected to the fertilizer arm from one end closes the fertilizer drop opening at the end of the hopper. This gate is opened by a control spring**.**

6. Control spring:

The used feeding device is a spiral compressed spring connected to the control arm from its ends and fixed from the other end to the machine frame, where it closes the gate. It is calibrated to allow the required amount of fertilizer to pass into the fertilizing arm and then re-close automatically by spring pressure. It is taken power from Fertilizing arm

7. Machine frame:

It is a rectangular steel frame that carries all the previous machine components, and connected to the three-point hitches.

8. Tractor:

Based on the required power for the manufactured machine, a 43 hp Kubota tractor was used. It was 4-cylinders with fuel tank capacity of 42 L, 540 rpm, overall length of 3305 mm, width of 1585 mm and height of 2405 mm.

2.2. METHODS

Main experiments were conducted to develop and evaluate the performance of a fertilizing machine for mango trees. Preliminary experiments were conducted to develop a local fertilizing machine. The performance of the developed machine was experimentally measured under the following parameters:

1. Four different machine forward speeds of 1.6, 2.0, 2.5 and 3.4 km/h.
2. Three different fertilizing depths of 8, 12 and 20cm.
3. Three different soil moisture contents of 24.51, 29.67 and 36.88% (MC_{db}).

2.3. MEASUREMENTS:

The evaluation of the mango tree fertilizing machine was carried out taking into account the following indicators:

2.3.1. Machine field capacity:

The field capacity of a farm machine is the rate at which it performs its primary function,

Table (٣): Specifications of the tractor used in fertilizing:

Specification	Details
Model	Kubota L1-43 Gasoline
Engine Power	43 HP (Horsepower)
Engine Type	4-Cylinder, Gasoline
Displacement	1,496 cc
Transmission	8 Forward, 4 Reverse Gears
Hydraulic System	Open Center
Lift Capacity (3-Point Hitch)	1,200 kg
Fuel Tank Capacity	42 Liters
PTO (Power Take-Off)	540 RPM
Overall Length	3,305 mm
Overall Width	1,585 mm
Overall Height	2,405 mm
Wheelbase	1,850 mm
Weight	Approximately 1,450 kg
Brakes	Wet Disc Brakes
Tire Size (Front)	6.00-16
Tire Size (Rear)	11.2-24

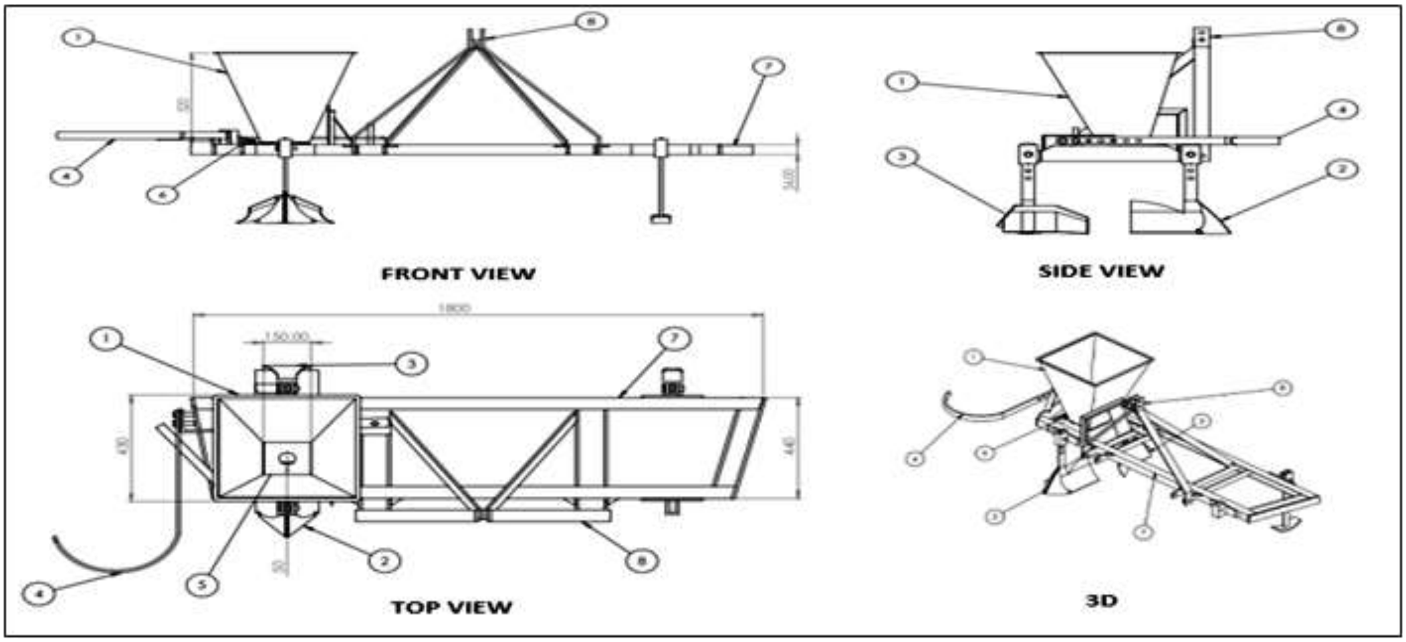

Fig. (2.3): Engineering drawing of the tree fertilizing machine

a. Theoretical field capacity ($F.C_{th}$):

$$F.C_{act} = \frac{W \times S}{Const.}\ ,\ fed/h.................(1)$$

b. Actual field capacity ($F.C_{act}$):

$$F.C_{act} = \frac{1}{AT}\ ,fed/h.....................(2)$$

Where: W= Working width (distance between tree rows), m.
S= Average machine forward speed, km/h.
AT= Actual total time, h/fed.

2.3.2. Machine field efficiency:

The field efficiency is the ratio between the productivity of a machine under field conditions and the theoretical maximum productivity. It can be calculated as follows:

$$\eta_f = \frac{F.C_{act}}{F.C_{th}} \times 100,\ \%...............(3)$$

Where: η_f = Machine field efficiency, %.
$F.C_{th}$ = Theoretical field capacity, fed/h.
$F.C_{act}$ = Actual field capacity, fed/h.

2.3.3. Power required:

To estimate the required power (Po, kW) during fertilizing process, the fuel consumption per unit time was determined by using a calibrated tank (Refilling method) to measure the volume of fuel consumed during the operation time. . The following formula was used to estimate the engine power **(Hunt, 1983)**:

$$Po = \left[F.C \times \frac{1}{3600} \times \rho f \times L.C.V \times 427 \times \eta_{thb} \times \eta_m \times \frac{1}{75} \times \frac{1}{1.36}\right], kW$$
$$.......(4)$$

n, (l/h).
ρf = Density of fuel, (kg/l), (for gasoline = 0.72 kg/l).
L.C.V = Calorific value of fuel, (11.000 k.cal/kg).
η_{thb} = Thermal efficiency of the engine, (for Otto engine, 25%,).
427 = Thermo-mechanical equivalent, (kg.m/k.cal).
η_m = Mechanical efficiency of the engine, (for Otto engine, 85%).

2.3.4. Specific energy requirements:

The specific energy consumed (E, kW.h/fed) by the tractor while using the machine during the time, can be calculated as follows, **(EL-Sharabasy, 2011):**

$$E = \frac{Po}{F.C_{th}},\ kW.h/fed...............(5)$$

2.3.5. Operational cost:

The operating costs of the tree fertilizing machine were estimated using the following equation **(Awady *et al.*, 1982)**:

$$C_{op} = \frac{C_H\ (L.E/h)}{FC_{act}\ (fed/h)},\quad L.E/fed.................(6)$$

Where: C_{op}= Operational cost, L.E/fed.
$C_{H.}$= Hourly cost, L.E/h.

The hourly cost of tree fertilizing machine was determined using the following equation, (**Awady, 1978**):

$$C = \frac{P}{h}\left(\frac{1}{a} + \frac{i}{2} + t + r\right) + (1.2\,W.S.F) + \frac{m}{144}........(7)$$

Where: C_H = Hourly cost, L.E/h.
P = Price of machine, L.E.
h = Yearly working hours, h/year.
a = Life expectancy of the machine, year.
i = Interest rate/year.
t = Taxes, over heads ratio.
r = Repairs and maintenance ratio.

W = Engine power, hp.
S = Specific fuel consumption, l/hp.h.
F = Fuel price, L.E/l.
m = Monthly average wage, L.E.
1.2 = Factor accounting for lubrications.
144 = Reasonable estimation of monthly working.

2.3.6. Quantity of fertilizers:

Bags are used that are attached to the fertilizer outlet and have a capacity of 1.5 kg of fertilizer and are weighed using a digital scale.

2.3.7. Fertilizing efficiency:

It is the ratio between the amount of fertilizer applied for the tree in the field and the amount of fertilizer needed by each tree.

$$\eta_f = \frac{F_{App.}}{F_T} \times 100, \ \% \text{..............} (8)$$

Where: η_f = Fertilizing efficiency, %.
$F_{App.}$ = Amount of fertilizer applied for the tree, g.
F_T = Amount of fertilizer needed by each tree, g.

3. RESULTS AND DISCUSSIONS:

The results obtained are discussed under the following headings. The performance of developed fertilizing machine is affected by several factors such as: machine forward speed, fertilizing depth and soil moisture content.

3.1. Machine actual field capacity:

Related to the effect of machine forward speed on machine actual field capacity, **Fig.(3.1)** show that, at a constant fertilizing depth of 8 cm, increasing the machine forward speed from 1.6 to 3.4 km/h leads to increase in the actual field capacity of the fertilizing machine from 1.61 to 2.69; from 1.47 to 2.36, and from 1.63 to 2.96 fed/h at different soil moisture contents of 36.88, 29.67 and 24.51%, respectively. Increasing machine field capacity by increasing forward speed was attributed to decrease in fertilization time, these results are agreement with **EL-Sharabasy *et al.* (2022).** reported that increasing the forward speed of the machine increases the actual field capacity of machine.

Concerning to the effect of fertilizing depth of machine actual field capacity, **Fig.(3.1)** show that, at the constant machine forward speed of 3.4 km/h, increasing the fertilization depth from 8 to 20 cm resulted in a decrease in the actual field capacity of the fertilization machine from 2.69 to 1.99; from 2.36 to 2.26, and from 2.96 to 2.7 fed/h at different soil moisture contents of 36.88, 29.67 and 24.51%, respectively. Decreasing machine field capacity by increasing fertilization depth was attributed to the resistance facing the machine increases, which leads to a decrease in speed and field capacity, these results are consistent with **Watanabe *et al.* (2023),** reported that increasing the fertilizing depth results in a decrease in the actual machine field capacity.

As regard to the effect of soil moisture content on actual machine field capacity. **Fig.(3.1)** show that, at a constant machine forward speed of 3.4 km/h. decreased soil moisture content from 36.88 to 24.51% led to an increase in the actual field capacity from 2.69 to 2.96; from 2.04 to 2.9, and from 1.99 to 2.7 fed/h at different fertilization depth 8, 12 and 20cm, respectively. Increasing machine field capacity by decreasing soil moisture content was attributed to the soil resistance increases with the increase in moisture content above a certain limit which leads to a decrease in the field capacity of the machine. These results agree with **Kuzucu and Dökmen (2015),** reported that increasing soil moisture content decreases the actual field capacity of the machine.

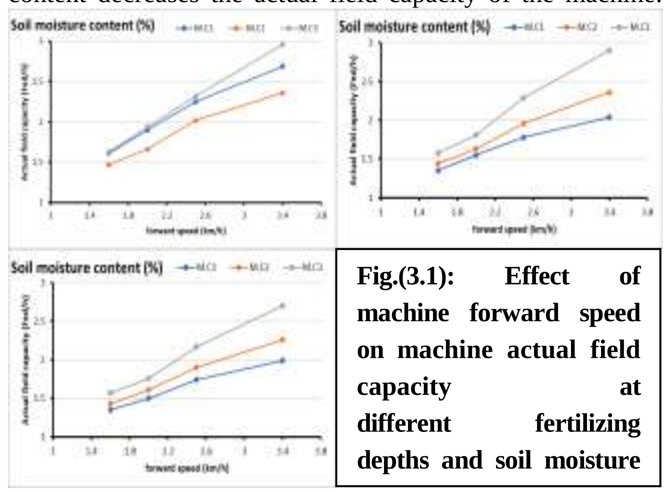

Fig.(3.1): Effect of machine forward speed on machine actual field capacity at different fertilizing depths and soil moisture

3.2. Machine field efficiency:

Related to the effect of forward speed of machine on actual field efficiency, data in **Fig.(3.2)** show that, at constant fertilizing depth of 8cm, increasing the machine forward speed from 1.6 to 3.4 km/h leads to decrease in the machine field efficiency from 78.16 to 76.86; from 65.04 to 56.06, and from 64.43 to 49.25 % at different soil moisture contents of 36.88, 29.67 and 24.51%, respectively. Decreasing machine field efficiency by increasing forward speed was attributed to the forward speed of the tractor is directly proportional to productivity and inversely proportional to field efficiency,these results agree with **EL-Sharabasy *et al.* (2022),** reported that increasing the forward speed of the machine decreases the field efficiency of machine.

Concerning to the effect of fertilizing depth on machine field efficiency, **Fig.(3.2)** show that, at constant machine forward speed of 1.6 km/h increasing the fertilization depth from 8 to 20cm led to a decrease in the machine field efficiency from 78.16 to 66.5; from 65.04 to 65, and from 64.43 to 63.82% at different soil moisture contents of 36.88, 29.67 and 24.51%, respectively. Decreasing machine field efficiency by increasing fertilization depth was attributed to increase in the time required for fertilizing due to the increased resistance encountered by the fertilizing unit, which leads to a decrease in the field efficiency, these results agree with **Chen *et al.* (2023),** reported that increasing the fertilizing depth of the machine leads to a decrease in the field efficiency of the machine.

As regard to the effect moisture content of the soil on machine field efficiency. **Fig.(3.2)** show that, at a constant machine forward speed of 3.4 km/h. decreased soil moisture content from 36.88 to 24.51% led to an increase in the machine field efficiency from 76.86 to 49.25; from 59.13 to 51.06, and from 58.19 to 51.63 % at different fertilization depth 8, 12 and 20cm, respectively. Increasing machine field efficiency by decreasing soil moisture content was attributed to the soil resistance increases with the increase in moisture content above a certain limit, which leads to a decrease in the field capacity of the machine and decrease in the field efficiency of the machine, these results agree with **De Vita et al. (2007)** reported that increasing soil moisture content results in decrease in the machine field efficiency at different fertilizing depth.

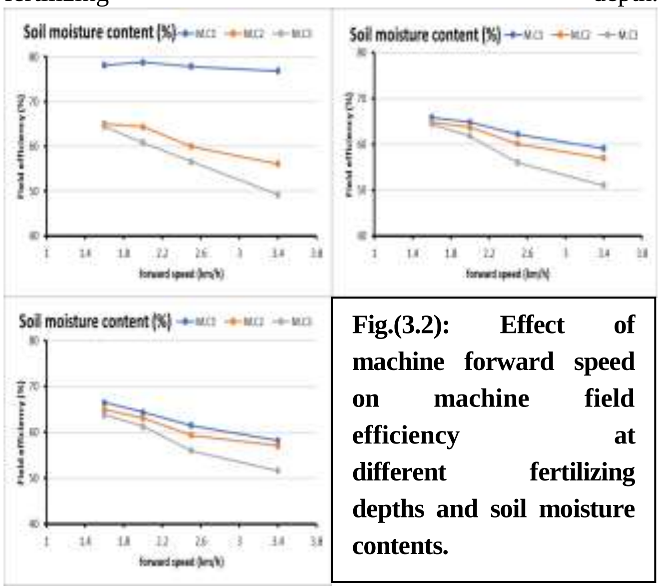

Fig.(3.2): Effect of machine forward speed on machine field efficiency at different fertilizing depths and soil moisture contents.

3.3. Quantity of fertilizers:

Related to the effect of machine forward speed on quantity of fertilizer, data in **Fig.(3.3)** show that, at a constant fertilizing depth of 12 cm, increasing the machine forward speed from 1.6 to 3.4 km/h leads to decrease in the quantity of fertilizer needed for trees from 900 to 416.7; from 900 to 383.3, and from 683.3 to 440.23 g/tree, at different soil moisture contents of 36.88, 29.67 and 24.51%, respectively. Decreasing quantity of fertilizer by increasing the machine forward speed was attributed to the reduction in the time required for the fertilization process, which leads to a reduction in the amount of fertilizer that comes down from the fertilizing unit, these results are compatible with **El-Mageed *et al.* (2015),** reported that increasing the forward speed of the machine decreases the quantity of fertilizer needed for trees.

Concerning to the effect of fertilizing depth of the machine on the quantity of fertilizer needed for trees, **Fig.(3.3)** show that, at the constant machine forward speed of 3.4 km/h, increasing the fertilizing depth from 8 to 20cm led to decrease in the quantity of fertilizer needed for trees from 466.7 to 399.2; from 450 to 366.7, and from 483.3 to 400 g/tree, at different soil moisture contents of 36.88, 29.67 and 24.51%, respectively. By increasing the depth of fertilization, the time required for the fertilizer to fall increases, which leads to a reduction in the amount of fertilizer, these results agreed with **Heidarisoltanabadi *et al.* (2024),** reported that increasing the fertilizing depth of the machine results in a decrease in the quantity of fertilizer needed for trees.

As regard to the effect moisture content of the soil on quantity of fertilizer needed for trees, **Fig.(3.3)** show that, at a constant machine forward speed of 2 km/h , decreased soil moisture content from 36.88% to 24.51% led to decrease in the quantity of fertilizer needed for trees from 933.3 to 833.3; from 900 to 683.3, and from 795 to 566.67g/tree, at different fertilization depth 8, 12 and 20cm, respectively. Decreasing quantity of fertilizer by decreasing the soil moisture content was attributed to the soil resistance increases with the increase in moisture content above a certain limit, which leads to decrease in the quantity of fertilizer needed for trees, These results agreed with **Kuzucu and Dökmen (2015),** reported that increasing soil moisture content results in an increase in the quantity of fertilizer needed for trees at different fertilizing depth.

3.4. Fertilizing efficiency:

Related to the effect of forward speed of machine on fertilizing efficiency, data in **Fig.(3.4)** show that, at a constant fertilizing depth of 8 cm, increasing the machine forward speed from 1.6 to 3.4 km/h leads to decrease in fertilizing efficiency from 93.33 to 46.67; from 100 to 45, and from 83.33 to 48.33 % at different soil moisture contents of 36.88, 29.67 and 24.51%, respectively. Decreasing fertilizing efficiency by increasing the machine forward speed was attributed to decrease the quantity of fertilizer with increasing forward speeds and thus the efficiency of the fertilizing arm was decreased, these results are in agreement with **EL-Sharabasy *et al.* (2022)** which states that increasing the forward speed of the machine leads to a decrease in fertilizing efficiency.

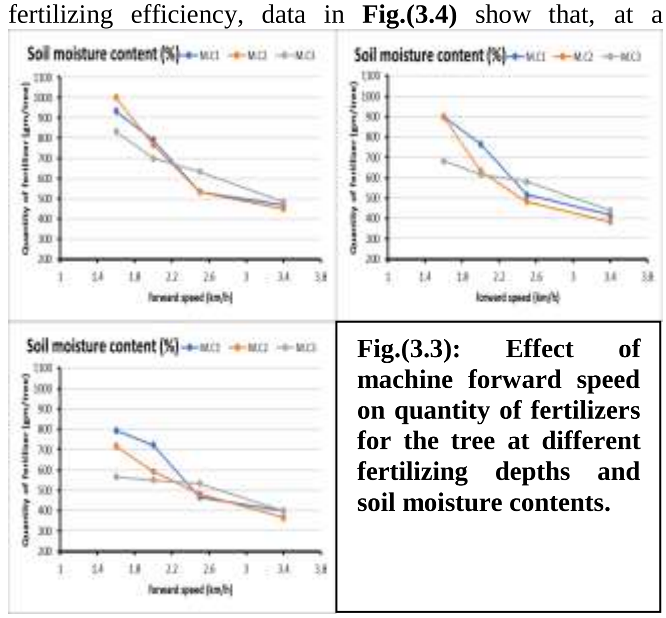

Fig.(3.3): Effect of machine forward speed on quantity of fertilizers for the tree at different fertilizing depths and soil moisture contents.

Concerning to the effect of fertilizing depth of the machine and fertilizing efficiency, **Fig. (3.4)** show that, at the constant machine forward speed of 1.6 km/h, increasing the fertilizing depth from 8 to 20 led to decrease in fertilizing efficiency from 93.33 to 79.5; from 100 to 71.67, and from 83.33 to 56.67%, at different soil moisture contents of 36.88, 29.67 and 24.51%, respectively. Decreasing fertilizing efficiency by increasing the fertilization depth was attributed to increase the time required for fertilizing and also leads to a decrease in the forward speed of the tractor due to the increased resistance faced by the fertilizing unit, which leads to a decrease in the field efficiency and thus fertilizing efficiency, these results agreed with **Chen *et al.* (2023)** reported, where they reported that increasing the fertilizing depth of the machine leads to a decrease in the field efficiency of the machine, which leads to a decrease in fertilizing efficiency.

As regard to the effect moisture content of the soil on fertilizing efficiency, **Fig. (3.4)** show that, at a constant machine forward speed ١.٦ km/h, decreasing soil moisture content from 36.88% to 24.51% led to decrease in fertilizer arm efficiency from 93.33 to 83.33; from 90 to 68.33, and from 79.5 to 56.67 % at different fertilization depth 8, 12 and 20cm, respectively. Decreasing fertilizing efficiency by decreasing the soil moisture content was attributed to the soil resistance increases with increasing moisture content above a certain limit, which leads to a decrease in the field capacity of the machine and a decrease in the fertilizing efficiency, these results agreed with **De Vita *et al.* (2007),** reported that decreasing soil moisture content leads to a decrease in the fertilizing efficiency of the machine at different fertilizing depths.

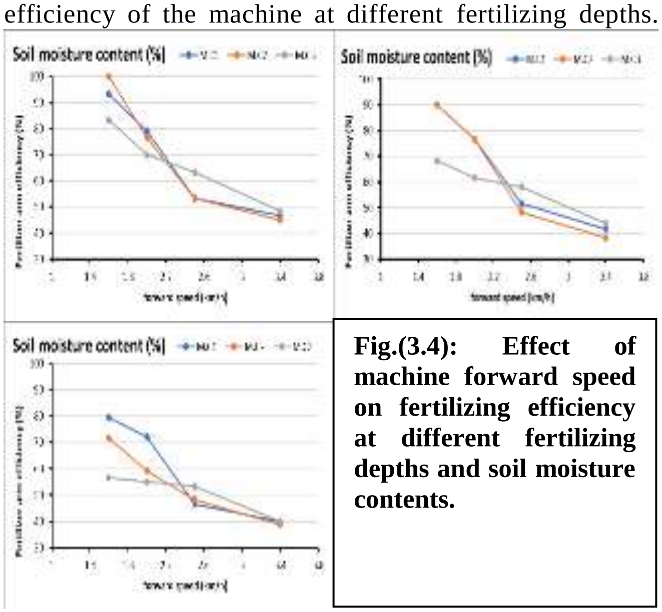

Fig.(3.4): Effect of machine forward speed on fertilizing efficiency at different fertilizing depths and soil moisture contents.

3.5. Specific energy requirements:

Related to the effect of forward speed of machine on specific energy consumed, data in **Fig.(3.5)** show that, at a constant fertilizing depth of 8 cm, increasing the machine forward speed from 1.6 to 3.4 km/h leads to decrease in specific energy consumed from 2.58 to 2.55; from 2.67 to 2.50, and from 2.87 to 2.60 kW.h/fed at different soil moisture contents of 36.88, 29.67 and 24.51%, respectively. Increasing forward speed, the power required was increased, but an increase in the field capacity is greater than an increase in power required, and thus the specific energy was decreased. The obtained results are consistent with **kim *et al.* (2020),** reported that increasing the forward speed of the machine decreases the machine energy consumed.

Concerning to the effect of fertilizing depth of the machine and the energy consumed. **Fig.(3.5)** show that, at the constant machine forward speed of 2.5 km/h, increasing the fertilizing depth from 8 to 20 led to increase in specific energy consumed from 2.59 to 2.63; from 2.51 to 2.57, and from 2.66 to 2.71 kW.h/fed, at different soil moisture contents of 36.88, 29.67 and 24.51%, respectively. Increasing energy consumption with increasing the fertilization depth was attributed to increased soil resistance and decreased field capacity which leads to an increase in the specific energy required, these results agreed with **EL-Sharabasy *et al.* (2022),** reported that increasing the fertilizing depth of the machine results in an increase in the machine energy consumed.

As regard to the effect of soil moisture content on the specific energy requirements, **Fig.(3.5)** show that, at a constant machine forward speed of ١.٦ km/h, decreased soil moisture content from 36.88 to 24.51% led to increase the specific energy consumed from 2.58 to 2.87; from 2.7 to 2.84, and from 2.61 to 2.82 kW.h/fed, at different fertilization depth of 8, 12 and 20 cm, respectively. As the soil moisture content was increased, the required power was increased, but the increase in power was less than the field capacity, so the specific energy requirements was decreased by increasing soil moisture content, the results obtained are consistent with **Aday *et al.* (2014),** reported that increasing soil moisture content results in an increase in the machine energy consumed.

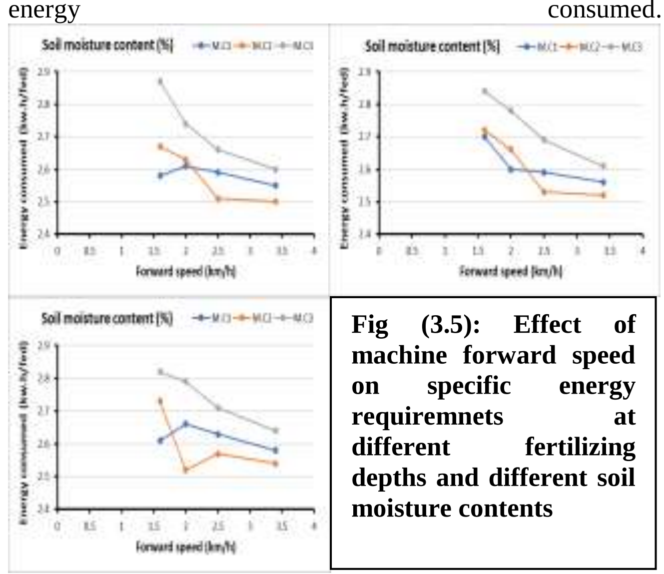

Fig (3.5): Effect of machine forward speed on specific energy requiremnets at different fertilizing depths and different soil moisture contents

3.6. Operational cost:

Related to the effect of forward speed on operational cost, data in **Fig.(3.6)** show that at a constant fertilizing depth of 8 cm, increasing the machine forward speed from 1.6 to 3.4 km/h leads to decrease in operational cost from 153.3 to 194.2; from 175.5 to 180.9, and from150.1 to 165.5 LE/Fed, at different soil moisture contents of 36.88, 29.67

and 24.51%, respectively. As forward speeds increased, power and hourly costs were increased and also field capacity was increased, but the rate of increase in field capacity was higher than the increase in hourly costs, so the operating cost was decreased as forward speed increased. these results are in agreement with **EL-Sharabasy *et al.* (2022)**, reported that increasing the forward speed of the machine decreases the operational Cost of machine.

Concerning to the effect of fertilizing depth of the machine on the operational cost, **Fig.(3.6)** show that, at the constant machine forward speed of 1.6 km/h, increasing the fertilizing depth from 8 to 20 cm led to increase in operational cost from 180.9 to 215.8; from 198.2 to 203.7, and from 178.7 to 185.5 LE/Fed, at different soil moisture contents of 36.88, 29.67 and 24.51%, respectively. As the depth increased, the soil resistance, fuel consumption and energy requirement increased, and thus the hourly cost was increased as the field capacity decreased, and thus, the operational cost was increased, these results are compatible with **EL-Sharabasy *et al.* (2022)** reported that increasing the fertilizing depth of the machine results in an increase in the operational Cost of machine.

As regard to the effect moisture content of the soil on the operational cost. **Fig.(3.6)** show that, at a constant machine forward speed of 3.4 km/h, decreased soil moisture content from 36.88% to 24.51% led to decrease in the operational cost from 108.3 to 98.4; from 142.8 to 100.4, and from 146.4 to 107.9 LE/fed, at different fertilization depth 8, 12 and 20cm, respectively. Decreasing operational cost by decreasing the soil moisture content was attributed to the soil resistance increases with the increase in moisture content above a certain limit, the resistance also increases in the case of dry, hard soil, which leads to an increase in the energy required for movement and thus the rate of fuel consumption, which leads to an increase in the cost required for operation.

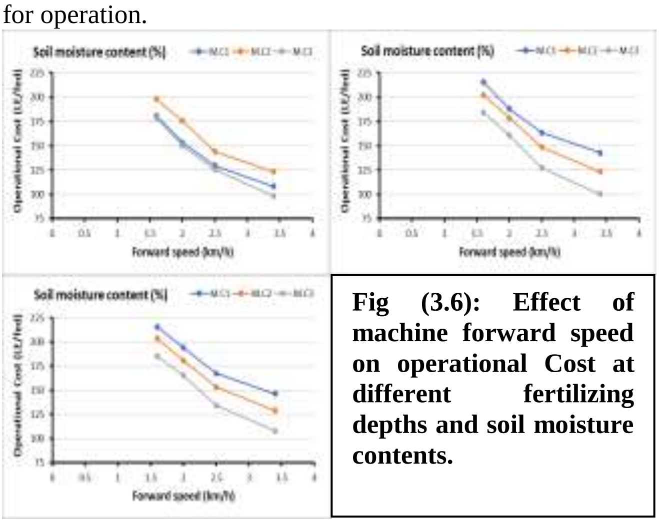

Fig (3.6): Effect of machine forward speed on operational Cost at different fertilizing depths and soil moisture contents.

The lower operating cost with lower soil moisture content is due to the fact that soil resistance increases with higher moisture content, which leads to higher energy requirements with lower field capacity, which leads to higher operating costs with higher moisture content,these results are compatible with **EL-Sharabasy *et al.* (2022)** reported that increasing soil moisture content results in an increase in the Operational Cost of machine at different fertilizing depth.

4. CONCLUSION:

Field experiments were conducted in clayey loam soil to evaluate the performance of the manufactured tree fertilizing unit. The results obtained from field experiments of mango tree fertilizing using the fertilizing machine manufactured under the following conditions: forward speed of the developed machine at 2 km/h, fertilizing depth of 8 cm, soil moisture content of 36.88%, which gave a field capacity of the machine was 1.9 fed/h, field efficiency rate of the machine was 78.84 %, fertilizing efficiency of 79.17%, quantity of fertilizer of 791.7 g/tree, specific energy consumption of 2.61 kWh/fed and operating costs of 153.3 LE/fed.

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CONFLICT OF INTEREST:

The authors declare that they have no conflict of interest.

AUTHORS CONTRIBUTION:

All authors developed the concept of the manuscript. Authors wrote the manuscript and achieved the experimental work and measurements. All authors checked and confirmed the final revised manuscript.

5. REFERENCES:

Aday, S. H; K. H. Huthily and Q. B. AL-Yasiri (2014): Effect of the Forward Speed and the Operating Depth of the Subsoil Laying Manure Machine on some of Sorghum Crop (*Sorghum bicolor* L. *moench*) Growth and Yield Parameters. Basrah Journal of Agricultural Sciences, 27(1), 293-302

Awady, M. N. (1978): Engineering of tractors and agriculture machinery. Text book. Col. Ag. Ain-Shams Univ., 5th Ed.,164 – 167.

El-Awady, M. N., Ghoniem, E. Y., and Hashish, A. I. (1982): A critical comparison between wheat combine harvesters under Egyptian conditions.

Bakhsh, K. H. U. D. A., Hassan, I. S. H. T. I. A. Q., and Akhter, M. S. (2006): Profitability and cost in growing mango orchards. Journal of Agriculture and Social Sciences, 2(1), 1813-2235.

Carranca, C., Brunetto, G., and Tagliavini, M. (2018): Nitrogen nutrition of fruit trees to reconcile productivity and environmental concerns. Plants, 7(1), 4.

Chatzistathis, T., Kavvadias, V., Sotiropoulos, T., and Papadaks, I. E. (2021): Organic fertilizing and tree orchards. Agriculture, 11(8), 692.

Chen, H., Gao, L., Li, M., Liao, Y., and Liao, Q. (2023): Fertilizing depth effect on mechanized direct- seeded winter rapeseed yield and fertilizer use efficiency. Journal of the Science of Food and Agriculture, 103(5), 2574-2584.

De Vita, P., Di Paolo, E., Fecondo, G., Di Fonzo, N., and Pisante, M. (2007): No-tillage and conventional tillage effects on durum wheat yield, grain quality and soil moisture content in southern Italy. Soil and tillage research, 92(1-2), 69-78.

El-Mageed, A., Ismail, N. K., and El-Tantawy, M. M. (2015): Application Fertilizer Controller Using a Simple Electronic Circuit Connecting with Fertilizing Device.

El-Sharabasy, M. (2011): Manually operated planter for planting different seeds in small areas. Misr Journal of Agricultural Engineering, 28(4), 865-882.

El-Sharabasy, M. M. A., and Saad, H. M. (2022): Fabrication and performance evaluation of a potato planter under Egyptian conditions. Damietta Journal of Agricultural Sciences, 1(2), 20–34.

Heidarisoltanabadi, M., Elhami, B., Imanmehr, A., and Khadivi, A. (2024): Determination of the most appropriate fertilizing method for apple trees using multi- criteria decision- making (MCDM) approaches. Food Science & Nutrition, 12(2), 1158-1169.

Hunt, D. R. (1983): Farm power and machinery management seedling machines eight edition: 102-111.

Kim, Y. S., Kim, W. S., Siddique, M. A. A., Baek, S. Y., Baek, S. M., Cheon, S. H., and Kim, Y. J. (2020): Power transmission efficiency analysis of 42 kW power agricultural tractor according to tillage depth during moldboard plowing. Agronomy, 10(9), 1263.

Kuzucu, M., and Dökmen, F. (2015): The effects of tillage on soil water content in dry areas. Agriculture and agricultural science procedia, 4, 126-132.

Milošević, T., and Milošević, N. (2020): Soil fertility: Plant nutrition vis-à-vis fruit yield and quality of stone fruits. Fruit Crops, 583-606.

Morad, M. M; M. M. A. El-Sharabasy, I. Yehia and F. A. Abdelgawad (2012): Development and performance evaluation of garlic-cloves planter. Misr Journal of Agricultural Engineering, 29(3), 993-1014.

Oberoi, A., Basavaraju, S., and Lekshmi, S. (2017, December): Effective implementation of automated fertilizing unit using analog pH sensor and Arduino. In 2017 IEEE International Conference on Computational Intelligence and Computing Research (ICCIC) (pp. 1-5). IEEE.

Subba-Rao N.S.; G.S. Venkaferaman, and S. Kannaiyan, (1993): Biological Nitrogen Fixatin. India Council. Agric. Res., New Delhi, p. 112.

Taki, O., and Asadi, A. (2018): Development and evaluation of a hydraulic hole digger for spot treatment of landscapes and orchards. Agricultural Mechanization and Systems Research, 18(69), 47-58.

Watanabe, K., Thienyaem, T., Poniyom, K., Saensupo, S., Sriroth, K., and Jaiphong, T. (2023): Effects of fertilizer application depth on the above-and belowground growth of sugarcane under different water regimes and machinery performance. Sugar Tech, 25(5), 1092-1101.

تصنيع وتقييم أداء وحدة أوتوماتيكية لتسميد الأشجار

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أجريت تجارب لتصنيع وتقييم وحدة تسميد أشجار أوتوماتيكية مناسبة للظروف المصرية، وتم دراسة أداء الآلة المطورة وفقاً للمعايير التالية: أربع سرعات أمامية مختلفة للآلة (١.٦، ٢.٠، ٢.٥ و٣.٤ كم/س)، وثلاثة نسب مختلفة لرطوبة التربة (٢٤.٥١، ٢٩.٦٧ و٣٦.٨٨%) وثلاثة أعماق مختلفة للتسميد (٨، ١٢ و٢٠ سم). وتم تقييم أداء الآلة المصنعة مع الأخذ في الاعتبار المؤشرات التالية: كمية السماد اللازمة لكل شجرة، السعة الحقلية، الكفاءة الحقلية، الطاقة النوعية المستهلكه، وتكاليف التشغيل. تم تصميم الآلة لتعلق على الجهاز الهيدروليكي للجرار بحيث يتم التحكم فيها بواسطة السائق. يتم وضع السماد عند ملامسة ذراع الوحدة للشجرة. توصي الدراسة باستخدام وحدة التسميد المطوره الأوتوماتيكية محلية الصنع لتسميد أشجار المانجو تحت الظروف الآتية: سرعة أمامية للآلة ٢.٠ كم/س وعمق تسميد ٨ سم ومحتوى رطوبي للتربة ٣٦.٨٨٪ والتي أعطت سعة حقلية للآلة ١.٩ فدان/س والكفاءة الحقلية للآلة ٧٨.٨٤٪ وكفاءة التسميد ٧٩.١٧٪ وكمية السماد ٧٩١.٧ جم/شجرة والطاقة النوعية المستهلكة ٢.٦١ كيلووات.س/ف وتكاليف التشغيل لهذه الآلة المصنعة ١٥٣.٣ جنيه/فدان.