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Research Article

Development of an Automatic Control Unit for Granular Fertilization of Field Crops

Gaballa, E. Kh. A.[1], Darwish, M. R. A.[2], El Kawaga, S. El. El.[1] and EL-Didamony, M. I.[2,*]

[1] Agricultural Engineering Research Institute, Giza, Dokki, Egypt.
[2] Agricultural Engineering Department, Faculty of Agriculture, Tanta University, Egypt.
[*] Correspondence: el-didamony@agr.tanta.edu.eg

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automatic control system; fertilization; feeding mechanism.

Abstract:

The precision application of granular chemical fertilizers plays a vital role in optimizing crop yield while minimizing environmental impact. This study presents the developed of an automatic control system for targeted fertilization within plant root zones. The system integrates the main frame, fertilizer hoppers, feeding mechanism and an automatic control unit. Field tests were carried out at four forward speeds (1.62, 2.11, 2.55, and 3.55 km/h), three different fertilizing distance (planting distance), and three sensor distance (15, 20, and 25 cm). The quality of the fertilization process performance was determined the following performance indicators: fertilizer distribution uniformity, energy consumption, and operating costs. The results revealed that decreasing the machine's forward speed improves machine efficiency and, as a result fertilizer distribution uniformity. Increased forward speed of the machine reduces fertilizer distribution uniformity. Best uniformity was found at a forward speed of 1.62 km/h and plant sensor distances of 20 cm. At planting distances of 20, 25, and 30 cm, fertilizer distribution uniformity was (91.8, 92.81, and 94.61%), respectively. The lowest and highest value for actual field capacity were obtained. For energy consumption, the lowest operating costs were 0.87 fed/hour, 5.73 kWh/fed, and 137.36 pounds/fed), respectively, at a forward speed of the fertilizer machine of 3.05 km/hour.

1. Introduction

Agricultural production is one of the pillars of the national and global economy, and human power is considered one of the most important pillars of this economy and its main focus in the process of comprehensive and sustainable development. The preservation of agricultural soil and the environment from pollution comes in the first place and a priority for specialists in the field of agricultural production. Fertilizers increase crop yields by 40-60% to feed the growing population. Two main types of chemical fertilizers are produced in Egypt, which are nitrogen fertilizers and phosphate fertilizers.

Chemical fertilizers play an influential and effective role in agricultural development in the vertical direction to meet the limited cultivated areas, but the excess and lack of control over both the fertilizer dose of the plant and its appropriate placement next to it without covering it with the appropriate amount of soil affects harmfully on both of agricultural soils, humans, animals and fisheries. Signs of environmental chemical pollution have appeared that have the greatest danger to the human environment, which raised the concern of scientists interested in human safety, and one of the most important sources of this pollution is the increasing additions of fertilizers for the purpose of increasing agricultural production, which leads to the loss of part of it in the waterways, as well as an increase in the concentration of some elements within the plants that we consume beyond the permissible limit medically, and it also constitutes a burden on the farmer on the one hand, and a waste of a lot of money without interest, and raises the cost of the agricultural production process and a decrease in its quality on the other hand Pollution of plants and groundwater, which made it necessary to rationalize their use and reduce the amount of negative impact of excessive fertilization of agricultural crops.

A healthy orchard necessitates well-balanced nutrition. In order to achieve a high yield, fertilizer application in the proper amount and position is important (Aman Mahore1 et al., 2024). A fertilizer distribution apparatus with double-level screws in order to meet the physical requirements of fertilizer and improve fertilizing effects, it mainly consists of a work bin, a screw of steady flow transportation, a fertilizing screw and a driving chain (Chen Xiongfei1 et al., 2015). Manufactured a local machine to apply compost and chemical fertilizers for vegetable cultivation in sandy soils and evaluate its performance with the traditional method under different operational conditions. The manufactured machine consists mainly of ridger, compost fertilizers applicator, chemical fertilizers applicator and a covering unit. The experimental results revealed that the manufactured machine increased both the uniformity of fertilizer distribution and crop productivity and decreases energy requirements for both organic manure and chemical fertilizers under the conditions of 3.3 km/hr., machine forward speed, 120 rpm feed shaft rotating speed and 20 cm furrow depth (Salama et al., 2016).

A small, precise and practical fertilizing machine (Fu et al., 2017). This machine was mainly used in greenhouse, and it was intelligent and automatic. The fertilization machine used ARM9 S3C2440 microprocessor as the core of circuit control module. It was equipped with a fertilizer level monitoring alarm device and would alarm automatically when the fertilizer level was less than 15 cm, so that the staff could add fertilizer in time. The machine used the Geneva mechanism as fertilizer metering mechanism. By controlling the pulse frequency of the stepping motor, the amount of fertilization could be controlled to achieve quantitative precision fertilization. The simulation results showed that the fertilization device could discharge the fertilizer particles evenly.

Fertilizer application is one of the important aspects of crop production. The quality of fertilizer application is directly related to the growth of crops, and reasonable fertilizer application is one of the important measures to ensure high quality and high yield of crops (Liu et al., 2022). Fertilization increases efficiency and obtains better quality of product recovery in agricultural activities. It is one of the most important ways. Non-organic fertilizers mainly contain phosphate, nitrate, ammonium and potassium salts. Fertilizer industry is considered to be source of natural radionuclides and heavy metals as a potential source. It contains a large majority of heavy metals like Hg, Cd, As, Pb, Cu, Ni, and Cu; natural radionuclide like 238U, 232Th, and 210Po (FAO, 2009). Using fertilization and cultivation double acting unit on small farm decreased energy consumption while improving effective field capacity and field efficiency for fertilizing and weeding at a forward speed of 2.2 km/h and soil moisture content of 20% (Fouda et al., 2015).

Fertilizer spreading is solid state world-wide. Consequently, a technical development is to be performed to improve coefficient of variation of the fertilizer distribution and to increase the working width of the spreaders (Csizmazia and Andersson, 2000). The method of fertilizing the whole plantation leads to over fertilizing certain regions and under fertilizing others. Apart from waste resources and over fertilizing the excess fertilizer that gets leached into nearby water bodies constitute environmental hazard.

Furthermore, excessive fertilizer application causes land degradation and pollution through leaching and volatilization (Norton et al., 2005). The method by which fertilizer is applied is very important for raising food crops. Fertilizers applied in proper amounts with appropriate methods to improve yield (Ahmad et al., 2007). A fertilization position that is too far away from the roots can easily lead to poor crop absorption and low fertilizer utilization ratio, and a fertilization position that is too close to the roots can easily lead to problems with fertilizer burning the roots. Research by agronomists has shown that a reasonable fertilization position ensures maximum fertilizer absorption by the crop roots, improves fertilizer utilization ratio and is important for reducing fertilizer rate (Zhang et al., 2020).

The present work aims to establish a chemical fertilizer unit, integrated with automated control systems for the precise dosage of fertilizer, positioning it in the designated location and at the advised depth, subsequently covering it with the proper soil layer.

2. Materials and Methods

Design and implementation of an automatic control system for granular chemical fertilization targeting plant root Zones and the experiments were carried out through winter (season 2023) in the Rice Mechanization Center at Meet El-Deeba, Kafr El-Sheikh Governorate at approximately 31° 6′ N latitude, 30° 50′ E longitude, with an elevation of around 6 meters above sea level, the description of the control unit with fertilizing machine illustrated in the following parts:

2.1. Developed fertilizing machine

2.1.1. The main frame

The main frame is constructed from mild steel angles of rectangular shape it has dimensions of 1500×500 mm for width and length. On the front of the main frame, there are three hitch points welded to attach the developed machine for chemical fertilization which is equipped with the control unit to the tractor as shown in Figure (1).

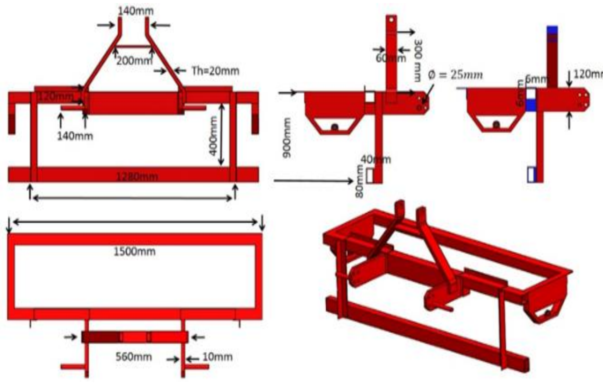

Figure 1. Main Frame.

2.1.2. Fertilizer hoppers

Two fertilizer hoppers Figure (2) were made of galvanized sheet having a square shape cross section at top 320×320 mm and a rectangular shape at the bottom with 8 mm thickness. The slop side of fertilizer hopper was designed according to coefficient of friction of fertilizer granules on galvanized sheet to facilitate the descent of fertilizer into the fertilizer feed cylinder. The fertilizer hopper carried above the main frame using a simple mechanism to easy adjustment above the plant rows according to the required distance. Each hopper has capacity of 25 kg of fertilizer. The feeding rollers are installed on the feeding shaft at the internal bottom of the fertilizer hopper.

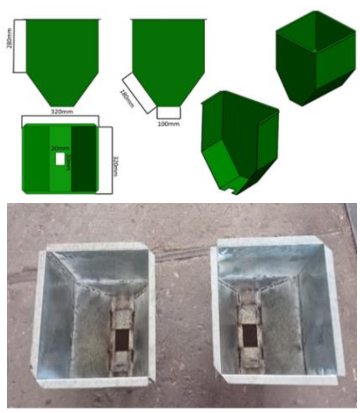

Figure 2. Fertilizer Hoppers.

2.1.3. Fertilizer funnel receiving

The development machine for chemical fertilization equipped with control unit receiving funnel is a rectangular V-shaped funnel with a length of 190 mm, a width of 80 mm, and sloping V-shaped sides with a height of 130 mm welded to a pipe with a diameter of 30 mm and a height of 50 mm for receiving fertilizer from the feeding rollers. The receiving funnels are installed on a frame under the fertilizer hopper and attached to the fertilizer tube as shown in Figure (3).

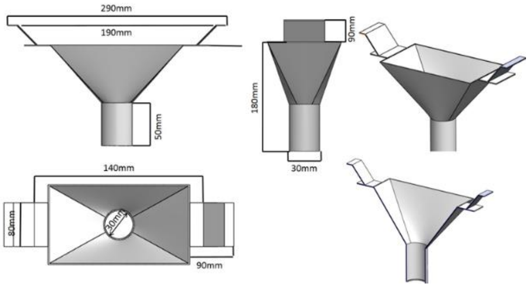

Figure 3. Fertilizer Funnel Receiving.

2.1.4. Fertilizer tubes

The Fertilizer tube in this type of Fertilizer has a smooth inner surface and a 25 mm diameter. It is attached to the end pipe of the Fertilizer delivery funnel in the bottom of the hopper that receive Fertilizer from hopper device and transport them to the furrow.

2.1.5. The fertilizer feeding shaft

The fertilizer feeding shaft is made of solid steel in a square shape with dimensions of 16×16×1500 mm and is fixed under the fertilizer hopper. Feeding rollers are mounted on the feeding shaft. which are fixed in rectangular holes on the internal bottom of the fertilizer hopper.

2.1.6. Fertilizer feeding rollers

The fertilizer feeding rollers were equipped with 4 cells on the circumference of the feeding roller, which is fabricated from Teflon material. The fertilizer cells have two different dimensions of cells one has a fixed depth of 14 mm and 19mm length and 15 mm width and another to give different feeding rates according to the kind of crop. The feeding rollers are installed on the feeding shaft at the internal bottom of the fertilizer hopper, as shown in Figure (4).

Figure 4. Fertilizer Feeding Rollers.

2.1.7. Automatic control unit

The automatic control unit of fertilizer feeding rates is an electronic circuit designed at rice mechanization center workshop. It has been tested and found to be operated with high efficiency. It mainly Consist of the following parts:

a- Dc motor

Dc motor Figure (5) operates at 24 V, and It used to operate fertilizer feeding rollers Its specification 24V ,60WATT,60rpm. The source of electrical energy is tractor battery 12 volts and due to the difference in potential voltage between them dc converter was used to convert the voltage from 12 to 24 Dc V.

Figure 5. Dc motor.

b- Dc converter

A DC-to-dc converter is an electronic circuit that converts a source of direct current (DC) from one voltage level to another. It is a type of electric power converter. Power levels range from very low (small batteries) to very high (high-voltage power transmission). It Convert the voltage from (12 - 34) v dc ,150watt and 7A.as shown in Figure (6).

Figure 6. Dc converter.

c- Four Hall Sensor Module

Four Hall Sensor Module are commonly used for measuring the RPM of rotating assemblies The Linear Hall Effect Sensor Module detects both North and South poles and relative strength of a magnetic field and provides both analog and digital outputs. It mainly consists of : 1) digital output, 2) vcc pin, 3) GND, 4) analog output, 5) potentiometer ,6) linear hall effect sensor and,7) lm 39comprator ic.as shown in figure (7).

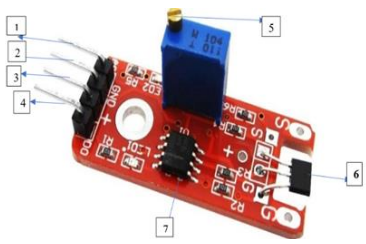

Figure 7. The Linear Hall Sensor Module.

Hall Effect Module Uses 49E analog Hall Effect sensor, can differentiate between North and South pole of the magnet, Detects the relative strength of the magnetic field, provides analog output representative of relative magnetic strength, provides digital output when magnetic strength exceeds the adjustable set-point, and 3.3 or 5V operation.

This module incorporates an analog Hall Effect sensor. Hall Effect sensors detect the presence of a magnetic field and are commonly used for measuring the RPM of rotating assemblies where a magnet on the assembly alternately makes and breaks magnetic contact with the sensor as the assembly rotates. They can even be used to detect electrical current flow through conductors in some cases. The Functional block diagram is shown in figure (8).

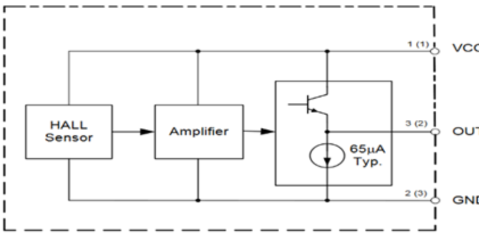

Figure 8. The Functional Block Diagram.

It contains an electronic circuit that spins the motor and operates the fertilization unit when the sensor touches the plant to fertilize it. This process continues until a certain amount of fertilizer is placed next to the plant. When the amount of fertilizer to be applied next to the plant is complete, this electrical component disconnects the motor at figure (9).

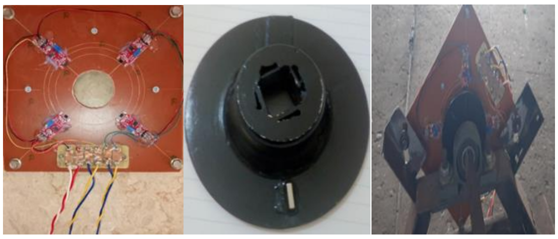

Figure 9. Hall Sensor Module.

d-Distribute and control circuit

Distribute and control circuit was designed to provide Four Hall Sensor Module with five volts. It mainly consists of 7 diode and switch. Since the Four Hall Sensor Module needs five volts to operate, an electronic piece was placed for this, and thus seven diodes were used to pass it and connect them to the operation switch to determine the cell size.

e-Plant sensor unit

It consists of an electric circuit, micro switch, power spring, aluminum arm and meatal base shown in figures (10 and 11).

1- An electric circuit

a) CMOS MC14044B: quad R−S latches are consisting of MOS P−Channel and N−Channel enhancement mode devices in a single monolithic structure. Each latch has an independent Q output and sets and reset inputs. The Q outputs are gated through three−state buffers having a common enable input. The outputs are enabled with a logical "1" or high on the enable input; a logical "0" or low disconnects the latch from the Q outputs, resulting in an open circuit at the Q outputs.

b) CMOS MC14069UB: the MC14069UB hex inverter is constructed with MOS P−channel and N−channel. Each of the six inverters is a single stage to minimize propagation delays.

2-Micro switches

Micro switches are mechanically operated electrical switches Consist of three pins: normally closed (NC), normally open (NO), and common (C). In the normal. It operates by using a spring-loaded lever to open and close a set of internal contacts inside the unit. When the aluminum arm touches the plant, the micro switch operates the electronic control circuit.

3-Aluminum Springs

Aluminum Springs are helix shaped springs that can store and release mechanical energy, absorb shock, or maintain a force between contacting surfaces.

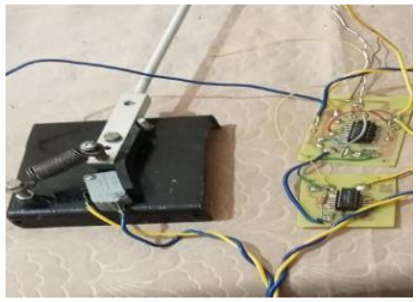

Figure 10. Plant Sensor Unit.

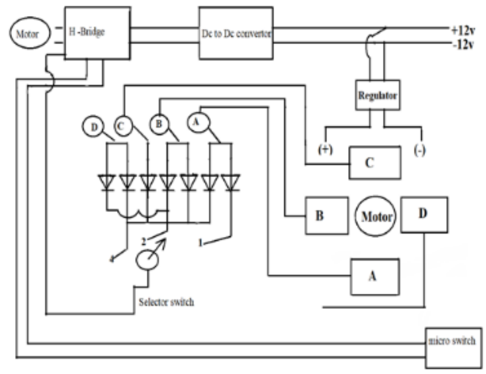

Figure 11. Diagram of automatic control unit.

2.1.8. Yanmar tractor YM500DT

A Yanmar tractor YM500DT (50 hp, 37.3 kW, 4WD) was used in the field experiment to mount the development machine on its three-hitch points device during the field experiments.

2.2. Field Experiments

The field experiments were carried out at four forward speeds (1.62, 2.11, 2.55, 3.05) and 3 sensor distance (20, 25, 30 cm).

2.3. Measurements

The performance of an automatic control system for granular chemical fertilization was evaluated through the following measurements:

a) Effective Field Capacity and Field Efficiency

The theoretical field capacity (T.F.C.) and the effective field capacity (E.F.C.) were calculated according to Kepner et al. (1982) as follows:

$$\textbf{Theoretical field capacity, T.F.C. (fed./h)} = \frac{\text{Machine width (m)} \times \text{Speed (km/h)}}{4.2}$$

$$\textbf{Effective field capacity, E.F.C. (fed./h)} = \frac{1}{\text{Total effective time (h) per feddan}}$$

The performance of an automatic control system for granular chemical fertilization was evaluated through the following measurements:

While the field efficiency (η_f) was calculated using the following formula:

$$\textbf{Field efficiency}, \eta_{f\,(\%)} = \frac{\text{E.F.C.}}{\text{T.F.C.}} \times 100$$

Where:
T.F.C. = Theoretical Field Capacity, fed./h.
E.F.C. = Effective Field Capacity, fed./h.

b) Fuel consumption

A measured volume of fuel was put into the fuel tank of the Yanmar tractor, which was used for mounting the development fertilizer machine before using in the field for a specific period. After the work was over, the volume left in the fuel tank was measured using a measuring jar. From these observations, the volume of fuel consumed was determined, and the rate of fuel consumption was calculated as follows:

$$\textbf{Fuel consumption} = \frac{\text{Fuel consumption (ml)}}{1000} \times \frac{60}{\text{Time of operation (min)}}$$

The fuel consumption per unit of area was determined by dividing the fuel consumption rate in L/h on the actual field capacity in feddan/h as follows:

$$\textbf{Fuel consumption (L/fed.)} = \frac{\textbf{fuel consumption (L/h)}}{\textbf{actual field capacity (fed./h)}}$$

Also, the specific fuel consumption (L/kW.h) was determined by dividing the fuel consumption rate in l/h on rated power of power unit in (kW) as follows:

$$\textbf{Specific fuel consumption} = \frac{\text{fuel consumption (L/h)}}{\text{Rated power (kW)}}$$

c) The power requirement

The total power **requirement** was calculated using the measured fuel consumption during the fertilizer under the different variables of the study. The following formula was used to estimate power requirement (EP) by the devolved fertilizer machine according to **Embaby (1985).**

$$\text{EP} = \left(F_c \times \frac{1}{60\times60}\right)\rho_f \times \text{L.C.V.} \times 427 \times \eta_{th} \times \eta_m \times \frac{1}{75} \times \frac{1}{1.36}\ \text{(kW)}$$

where:
F_c = Fuel consumption, L/h,
ρ_f = Density of diesel fuel (0.85 kg/L),
L.C.V. = Lower calorific value of diesel fuel (10000 kcal/kg),
427 = Thermo-mechanical equivalent, kg.m/kcal,
η_{th} = Thermal efficiency of diesel engine, (40%), and
η_m = Mechanical efficiency of diesel engine, (80%).

The energy consumed for developed fertilizer machine was calculated using the following equation:

$$\text{Energy consumption (kW.h/fed.)} = \frac{\text{Power requirement (kW)}}{\text{Effective field efficiency (fed/h)}}$$

d) Field efficiency (ηf, %)

Field efficiency was calculated as ratio of the effective field capacity (Efc, fed/h) to the theoretical field capacity (Tfc, fed/h), as the following formula, (Kepner et al., 1982):

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

e) Uniformity of fertilizers distribution

Standard deviation, coefficient of variation and coefficient of uniformity were calculated as the following: Coefficient of variation (C.V) was calculated as the following

$$xa = \frac{\sum xi}{n}$$

$$\delta = \sqrt{\frac{\sum(xi-xa)^2}{n-1}}$$

$$cv = \frac{\delta}{xa} \times 100$$

Where:
Xi: The individual collection points
Xa: The arithmetic meaning
n: Total number of collection points
δ: Standard deviation
C.V: Coefficient of variation (%)

Coefficient of uniformity (C.U %) was calculated as the following formula (Dragos, 1975).

$$C.U = 1 - \frac{\sqrt{\frac{\sum(xi-xa)^2}{n-1}}}{xa} \times 100$$

f) Cost Analysis

To carry out the cost analysis of the development fertilizer machine, operating costs were taken into consideration as follows: - costs of construction, which included manufacturing the parts of the development machine (. Fertilizing roller, Funnel Fertilizing, reception, fertilizing tube, electronic circle, Main frame., Fertilizing box., Fertilizing feeding shaft)

- Purchased parts costs, such as (Furrow opener)

- Machinery costs, which include fixed costs (depreciation, interest, housing, insurance, and taxes) and variable costs (repair and maintenance, fuel, oil, and labor).

The details of costs analysis (L.E./h) or (L.E./fed.) using development machine with a Yammer tractor (50 hp) as a power unit could be explained as follows:

1. Fixed costs items (FC)

- Depreciation (D): It is a reduction in value and usefulness. In this study, the average annual depreciation costs were determined using the following formulas: According to Hunt (2001), the annual depreciation charge can be written using the following equation.

$$D = (P - S) / L$$

Where:
D = Depreciation (L.E./year).
P = Machine/tractor purchase price, (L.E).
S = Salvage rate (L.E.), 10% purchase price and
L = Life years of the machine/tractor.

- Interest in investment (I): The average real annual interest rate was taken as 17%. The interest in investment (I) was calculated according to **Kepner et al. (1982)** as follows:

$$I = \frac{P+S}{2} \times 0.17$$

Where:
I = Interest in investment, L.E./year.
P = Machine/tractor purchase price, (L.E.) and
S = Salvage rate (L.E.), 10% purchase price.

- Tax, insurance, and shelter (TIS): According to Kepner et al. (1982), tax, shelter, and insurance can be calculated as 2% of the purchase price of the machine/tractor. Fixed costs were estimated according to the construction values listed in table (1)**.**

Table 1. Cost of construction for development machine based on prices in the year 2023.

Cost of construction for development machine based on prices in the year 2023			
Parts of development machine	**No. of units**	**Price of single unit (L.E.)**	**Total Price (L.E.)**
Fertilizing roller	4	60	120
Funnel Fertilizing reception		50	100
Fertilizing tube		20	40
Furrow opener		500	1000
Electronic circle	1	1500	1500
Main frame	1	3200	3200
Fertilizing box.	1	1250	1250
Fertilizing feeding shaft	1	300	300
Labor cost	1	3600	3600
Total price (L.E.)			11110

2. Variable costs (VC)

-Fuel and lubricants

Fuel and lubricants can be calculated as follows:

Fuel cost (L.E./h) = fuel consumption (L/h) × fuel price (L.E./L)

Oil, and lubricant cost (L.E./h) was calculated as 30% of fuel cost (Hunt, 1977). The price of diesel fuel is 6.75 L.E./L according to the prices in 2023.

- Repair and maintenance (RM)

Repair and maintenance can be assumed as 50% of purchase price for total age of the machine according to (Kaul and Egbo, 1985)

- Labor cost (LC)

Defined as the wage of the machine/operator, (L.E./h).

3. Machine total costs (TC)

The total costs of machine/tractor, (L.E./h) summation of the total fixed costs (L.E./h) and total variables costs (L.E./h) as follows:

Total operation costs, (LE/h) =Fixed costs, (LE/h) +Variable costs, (LE/h)

The total operating costs (L.E./fed.) were calculated by dividing the total operating costs (L.E/h.) on the effective field capacity (fed./h) as follows:

Total operating cost (L.E. /fed.) = (Total operating cost (L.E./ h))/ (Actual field capacity (fed./h))

2.4. Instruments

An electronic balance, stopwatch, measuring tape.

3. Results and Discussions

The field experiments of the developed fertilizing machine were carried out to evaluate the machine performance which includes energy consumed, power requirements, uniformity of fertilizers, tractor slip ratio, effective field capacity and efficiency, and cost Analysis.

3.1. Energy requirements

The data of energy requirement are shown in Figure (12), it could be observed that, an increase in forward speed decreases the values of energy requirement at any given load of the developed machine for chemical fertilization. due to increasing effective field capacity with increasing forward speed. The highest values of energy requirements were 11.00 and 12.94 kW.h/fed. were obtained at 1.62 and 2.11 km/h forward speed with normal and full load of the developed machine for chemical fertilization. While the lowest values of 4.90 and 5.73 kW.h/fed were obtained at a forward speed of 2.55and 3.05 km/h with normal and full load of the developed machine for chemical fertilization.

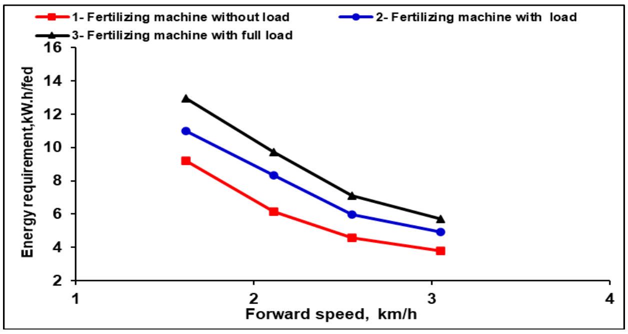

Figure 12. Energy requirement under forward speeds and normal/full loads of the developed machine for chemical fertilization.

3.2. Power consumption

The obtained values of power consumption under fertilizing forward speeds and normal/full loads of the developed machine for chemical fertilization equipped with control unit are shown in Figure (13).

These results may be due to increased fuel consumption with any increase in forward speed and the developed of machine for chemical fertilization load. The values of power consumption were 5.50, 5.35, 4.80, and 4.46 kW for using the developed machine for chemical fertilization at an 1.62, 2.11, 2.55, and 3.05 km/h forward speed with normal loads of the developed machine for chemical fertilization. The values of power consumption were 6.34, 6.03, 5.48, and 4.98 kW for using the developed machine for chemical fertilization at an 1.62, 2.11, 2.55, and 3.05 km/h forward speed with full loads of the developed machine for chemical fertilization.

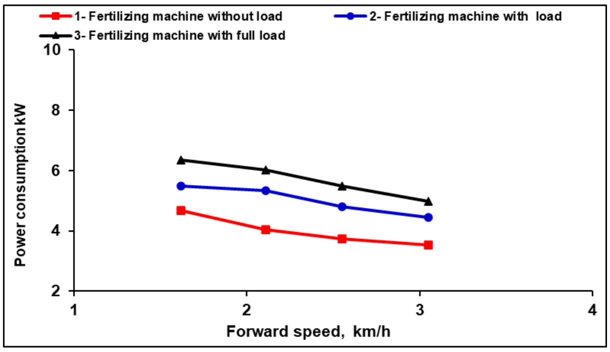

Figure 13. Power consumption under forward speeds and normal/full loads of the developed machine for chemical fertilization.

3.3. Uniformity of Fertilizers

The actual fertilizing spacing of fertilizing distribution during evaluation of fertilizing machine under different fertilizing distance, sensor distance and fertilizing forward speeds were measured to calculated, the coefficient of variation (C.V.), and the coefficient of distribution uniformity The results are shown. in Figures (14, 15 and 16).

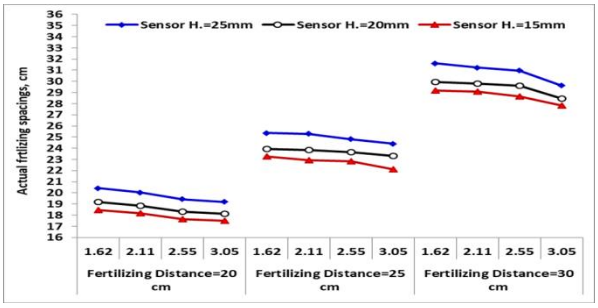

Figure 14. Actual fertilizing spacing of fertilizing distribution during evaluation of fertilizing machine under different fertilizing distance, sensor distance and fertilizing forward speeds.

The obtained results showed at figures (18, 19, and 20) demonstrated a negative relationship between the effects of distance sensor and forward speed on the coefficient of variation (C.V.) at any fertilizing distance. At distance sensor 20cm the coefficient of variation (C.V.) were 8.82,13.02 ,14.30, 18.53 %at four Forward speeds respectively, the coefficient of variation (C.V.) were 7.11,10.93 ,13.11, 15.38 %at fertilizing distance 25 cm .and the coefficient of variation (C.V.) were 5.39,8.83 ,10.51, 13.98 %at fertilizing distance 30 cm, and fertilizing forward speed 1.62, 2.11, 2.55, 3.05 km /h.

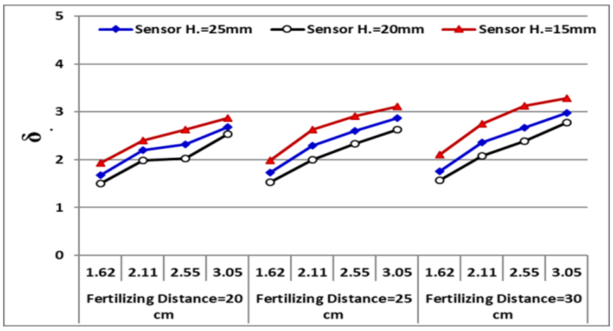

Figure 15. Standard deviation (δ) of fertilizing distribution during evaluation of fertilizing machine under different fertilizing distance, sensor distance and fertilizing forward speeds.

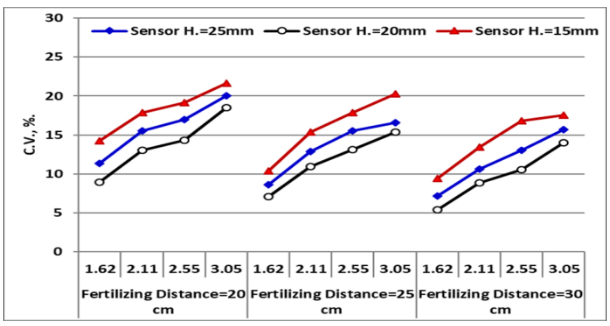

Figure 16. Coefficient of variation (C.V %) of fertilizing distribution during evaluation of fertilizing machine under different fertilizing distance, sensor distance and fertilizing forward speeds.

The obtained results of the fertilizer distribution uniformity coefficient for fertilizing machine under different fertilizing distance, sensor distance and fertilizing forward speeds are explained on Figure (17). From this Figure, it could be cleared that the coefficient of fertilizing distribution uniformity was increased by increasing fertilizing distance and decreased the fertilizing forward speed. The highest values of uniformity were 91.08, 92.89 and 94.61% at distance sensor 20 cm and fertilizing distance 20,25,30 cm. at the fertilizing forward speed of 1.62 km/h and while, the coefficient of fertilizing distribution uniformity decreased from 91.08 to 81.47%, 92.89 to 84.62% and 94.61 to86.02% with increasing forward speed from 1.62 to 3.05 km/h at distance fertilizing 20,25,30 cm.

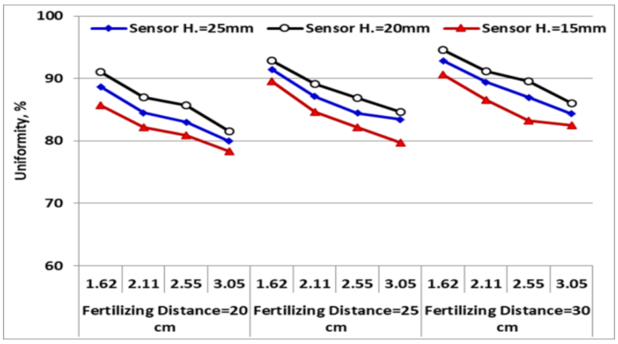

Figure 17. Coefficient of uniformity (C.U %) of fertilizing distribution during evaluation of fertilizing machine under different fertilizing distance, sensor distance and fertilizing forward speeds.

3.4. Slip ratio

Measuring values of the slip ratio for the tractor used to developed machine for chemical fertilization equipped with control units during evaluation the variables study in Figure (18). The obtained results of tractor slip ratio showed that an increase in fertilizing forward speed increased the values of tractor slip ratio. The average values of the tractor slip ratio were 1.63,2.25,3.20, and 4.58% under the fertilizing forward speed of 1.62, 2.11,2.55 and 3.05 km/h, respectively, during the machine without load compared with 2.90,3.70,4.50 and 5.38% for full load of the developed of machine.

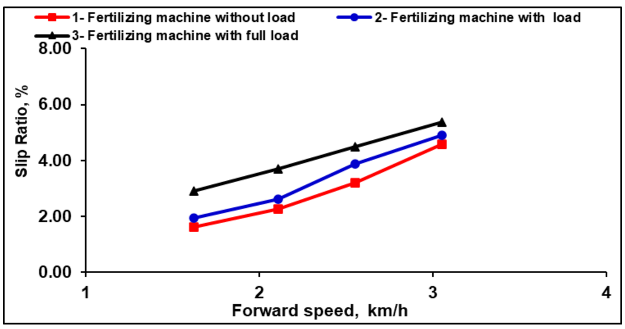

Figure 18. Tractor slip ratio during evaluation of developed machine under different loads and fertilizing forward speeds.

3.5. Effective field capacity and efficiency

The obtained results of the effective field capacity for the developed machine under the variables study shown in Figure (19). From this Figure, it could be concluded that an increase in fertilizing forward speed results in an increase in effective field capacity at any given load for the developed machine. The values of effective field capacity of 0.50, 0.64,0.80, and 0.91 fed./h were obtained when using the developed machine with normal load at 1.62,2.12,2.66 and 2.98 km/h fertilizing forward speeds, respectively, compared with .0.49, 0.62,0.77 and 0.87 fed./h when using the developed machine with full load under the forward speed 1.59,2.04,2.55 and 2.84 km/h.

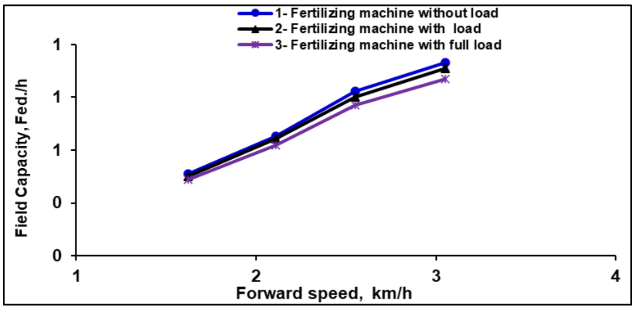

Figure 19. Effective field capacity under different fertilizing forward speeds and normal/full loads of developed machine.

The obtained results of the effective field efficiency for the developed machine for chemical fertilization under forward speed are shown in Figure (20). From this Figure, it could be shown that an increase in fertilizing forward speed results in a decrease in field efficiency at any given load for the developed machine for chemical fertilization. These results may be due to the increased tractor wheel slip ratio with an increasing load. the field efficiency values of 97.37,96.34,94.43 and 87.67% were obtained for using the developed machine for chemical fertilization. Under normal load, compared with 95.44,92.83, 90.72 and 83.92 % for using the developed machine for chemical fertilization under full load at 1.62,2.11, 2.55 and 3.05 km/h forward speeds, respectively. In general, the findings showed that any increase in forward speed led to decreased operating times, which resulted in increased effective field capacity. But field efficiency decreased by increasing forward speed, which may be due to the increase in theoretical field capacity.

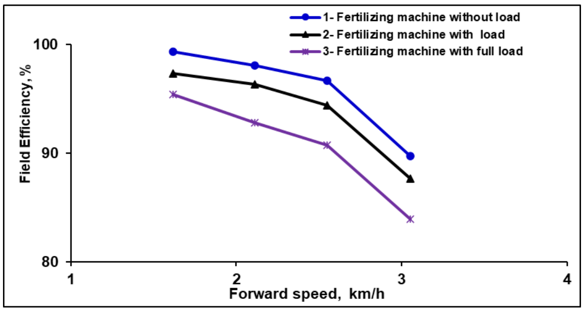

Figure 20. Effective field efficiency under different fertilizing forward speeds and normal/full loads of developed machine.

3.6. Cost Analysis

The cost analysis total machinery operating cost, under study of the fertilizing machine and the tractor used during fertilizing plant, which include fixed and variable costs and the most important assumptions used in calculating these costs were summarized in Table (2) The obtained values of the total cost of operation for each the tractor and the fertilizing machine were 204.49, 163.61, 141.36 and 137.36 LE/fed., under different forward speeds of 1.62, 2.11, 2.55 and 3.05 km/h.

Table 2. Total operating costs of the fertilizing machine and the tractor used during fertilizing plant.

Category		Symbol	Planer	
Fixed costs of tractor, (L.E.)		P	180000	
Fixed costs of fertilizing machine, (L.E.)			11110	
Working hours (h/year)		h	1000	
Life expecting of the machine (year)		li	10	
Interest from the cost of machine		I	17	
Repair and maintenance, % of the purchase price of the machine for 10 years.		r	50	
Taxes over heads from the cost of machines		T	2	
Fuel price, L.E./L		F	6.75	
Forward speed, km/h	1.62	2.11	2.55	3.05
Total Fixed cost (FC), L.E./h	37.49	37.49	37.49	37.49
Fuel consumption L/h	3.91	4.03	4.92	6.11
Fuel cost (f), L.E./h	26.40	27.22	33.19	41.26
Oil and lubricant cost (OL), L.E./h	7.92	8.17	9.96	12.38
Labor wag (Lw), L.E./h	25.00	25.00	25.00	25.00
Repair and maintenance (RM), L.E./h	0.56	0.56	0.56	0.56
Total variable cost (VC), L.E./h	59.88	60.94	68.70	79.20
Tractor hourly cost, L.E./h	97.37	98.43	106.19	116.69
Fertilizing machine cost, L.E./h	2.82	2.82	2.82	2.82
Total hourly cost, L.E./h	100.18	101.25	109.00	119.51
Field capacity, fed./h	0.49	0.62	0.77	0.87
Operating cost, L.E./fed.	204.49	163.61	141.36	137.36

4. Conclusions

The study aims to develop a mechanical unit for chemical fertilization equipped with an automatic control system for fertilizer dosage for the plant and placing it in the appropriate space and at the recommended depth next to it, while covering it with the appropriate soil cover. The results showed that reducing the forward speed of the machine increases the efficiency of the machine and thus increases the uniformity of fertilizer distribution. As the forward speed of the machine increases, the uniformity of fertilizer distribution decreases. It was found that the best uniformity was at a forward speed of 1.62 km/h and a distance to the plant sensor of 20 cm. At planting distances 30 cm, the uniformity of fertilizer distribution was 94.61%. The highest value of actual field capacity, the lowest value of energy consumption, and the lowest value of operating costs were obtained (0.87 fed/hour, 5.73 kWh/fed, and 137.36 pounds/fed), respectively, at a forward speed of the fertilizer machine of 3.05 km/h.

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