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Effect of Reservoir Tillage System and Organic Fertilization on Soil Water Erosion Resistance under Rainfed Conditions

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Abstract

Northwestern coastal region of Egypt is characterized by severe slop nature, which makes it more vulnerable to soil erosion by water. In addition to losing of the fertile surface soil layer, which causes its degradation and low productivity. This research aims to mitigate water soil erosion by applying a reservoir tillage system. Therefore, a planting and reservoir tillage machine (PRT) was locally manufactured to implement the reservoir tillage system and conducting mechanical planting of wheat crop in one pass. A field experiment was conducted under wheat crop grown condition on a sandy loam soil in Wadi El Raml during winter cultivation season of 2021-2022. This field experiment aims to investigate the effect of using a reservoir tillage system and organic fertilization on mitigation water soil erosion under rainfed condition. The statistical design of the experiment was a split plot with three replicates for each treatment. Main plots included two fertilization rates of farmyard manure of 0 and 25 m^3/ha. Sub main plots included three types of pits' dimensions which were 0.50×0.14×0.20 m (PD1), 0.60×0.17×0.14 m (PD2) and 0.70×0.20×0.10 m (PD3) for length× width× depth m, respectively with same volume of 10.35 liters. In addition to traditional cultivation as control treatment with three replicates. The results revealed that using the PRT machine at pit dimensions of PD1 with the addition of farmyard manure decreased the rainwater surface runoff and soil loss by about 85.67% and 74.76%, respectively, while increased wheat grain and straw yields and net profit by about 88.44% 79.69% and 73.97%, respectively, compared to the traditional cultivation.

Keywords: Reservoir tillage, Farmyard manure, Runoff, Soil loss, Rainwater, Wheat yield, Profit.

1. Introduction

There are about 1.05 million hectares of rainfed areas with length of 500 km and width of 20 km in the northwestern coastal zone of Egypt [1]. It suffers from soil erosion hazards, which is considered a serious problem that caused a decrease of soil quality and an increase of the soil resource degradation [2]. Soil erosion threatens rainfed agriculture in this region, which represents 70.1% of rainfed agriculture [3]. Valleys extend through the northern coast of Egypt, which is characterized by a slope nature towards the valley bottom. These valleys are considered the most exposed areas to water erosion due to the high amount of rainwater which is accumulated from the adjacent areas [4] and [5]**.** Wadi El Raml is one of the main wadis which extends from Fuka to Libyan-Egyptian border in the Northwestern Coast of Egypt (NWCE). It is located at west Matrouh city about 13 km and extended from southwest to northeast of the city (latitudes of 31° 09´ 00", 31° 21´ 00" N., longitudes of 27° 06´ 00", 27° 12´ 00" E.) This valley suffers from losing most of rainfall water with sediments by surface runoff to the Mediterranean Sea [6]. On the other hand, there are many factors that expose these areas to water erosion, such as the scarcity of natural cover and the lack of agricultural activities. So, it is necessary to adopt successful watershed management as water harvesting activities considering the topography of the area and soil properties to optimize the water use management efficiency according to the priority of use [7]. Water harvesting techniques have long been used as effective methods to reduce the effects of soil erosion and sedimentation and to promote soil, water storage and soil fertility [8]. The reservoir tillage is considered one of the most effective in-situ system of these methods used for reducing the negative impact of rainwater runoff causing soil erosion. In-situ reservoir tillage system has a vital role as one of water harvesting systems that mitigates the impact of soil erosion and conserves it by making small depressions or pits between crop rows to reduce runoff and hold water to percolate into these pits [9] and [10]. This technique is proper to rainfed agriculture or to sprinkler irrigation [11]. A new reservoir tillage system was designed for in-situ rainwater harvesting in semi-arid areas that included horizontal soil subsoiler, a raw planter and a roller formed with plastic wheels for making mini-reservoirs on the soil surface. The results indicated that this system could enhance the infiltration and delay runoff by about 20 minutes compared to the control treatment when a rainfall of 40 mm h^{-1} was simulated, thus soil erosion with rainwater was reduced [12]. Moreover, using an organic matter such as farmyard manure can enhance infiltration rate, water holding capacity, structure [13]. Therefore, the main objective of this work is to study the effect of using the reservoir tillage system and organic fertilization on controlling the water soil erosion under Wadi El-Raml conditions to maximize wheat crop productivity under rainfed conditions during winter season of 2021-2022.

2. Materials And Methods

A. Materials:

Tractor

Belarus tractor with diesel engine traction system 4×4, model 320SL and net rated power of 90 hp was used.

Chisel plow

A chisel plow with 7 blades and 1.75 m working width was used to carry out ploughing process to preparate a good seedbed.

Planting and reservoir tillage machine /(PRT).

The PRT machine was locally manufactured as a mounted type. It was attached to the tractor's hydraulic system via three-point hitches through a combination of three links, one was upper link and two were lower links. It consisted of main frame, mechanical planting unit, reservoir tillage unit and two ground wheels as shown in **Fig .(1)**.

Fig. (1) Parts of combination machine for planting and reservoir tillage.

1) Mechanical planting unit, 2) Reservoir tillage unit and 3) Toothed ground wheels.

Wheat crop

Winter wheat (Triticum aestivum L.), Giza 168 variety with sowing rate of 140 kg ha^{-1} was cultivated on 23 November in 2021.

Instruments:

Rain-gauge device.

It was locally manufactured and calibrated as shown in **Fig (2)** [14]. Each 1 mm on the calibrator of the device indicates to 1 mm of the amount of rainwater falling in the field.

Fig .(2) Rain gauge device for measuring rainwater falling in the field [14].

Fuel meter

Fuel meter device [15] was used to measure the volume of consumed fuel quantity per unit time accurately as shown in **Fig (3**). The length of line which marked by the marker tool on the paper sheet indicates to the fuel consumption. This equipment was calibrated prior to its use.

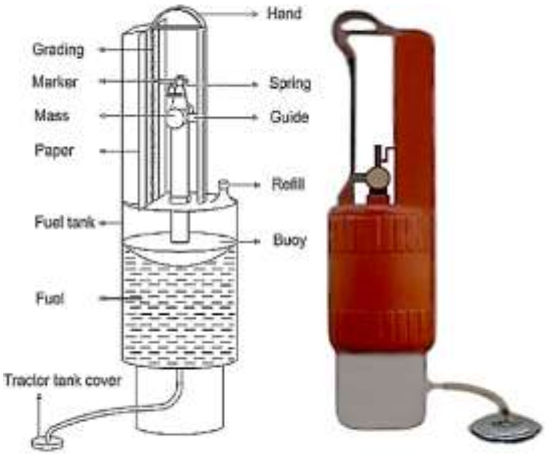

Fig. (3) Fuel meter for measuring fuel consumption [15].

Rainwater runoff and sediment Trough

It was fabricated from PVC material with rectangular shape. Its dimensions were 500 × 300 ×

200 mm for length × width × height mm, respectively, as shown in **Fig. (4)**. Each trough was installed in auger holes at the down-slope edge of each plot to receive and collect rainwater runoff and sediment. It has a drainage hole connected to the drain tube (gutter) fixed beneath its edge to transmit water runoff to receiving containers after extracting sediment. These troughs were covered so that rainwater could not enter, and evaporation was assumed to be negligible. The runoff volume was determined from the measured depth of water in each trough.

Fig (4) Trough used for collecting rainwater runoff.

1) container 2) trough.

B. Methods:

Experimental procedure

The field experiment caried out in winter cultivation season of 2021 - 2022 on area about 0.5 hectare of a sandy loam soil texture in Wadi El-Raml. This region located in northwestern coast zone (latitudes of 31° 09´ 00", 31° 21´ 00" N., longitudes of 27° 06´ 00", 27° 12´ 00" E.) as shown in **Fig. (5).** This region is characterized by average slope of 8% and some of soil physical and chemical properties were carried out according to [16]**,** respectively, as showed in **Table (1)**. The experiment was conducted to optimize value of the main operating parameters affecting the soil water erosion resistance under rainfed agriculture of wheat crop. Wheat seeds were planted by using two methods:

- The first method was carried out by using the manufactured planting and reservoir tillage machine (PRT) and adding of organic fertilization of farmyard manure (FYM) for seedbed preparation and planting in one pass.

- The second method was the traditional cultivation as it prevails in the study region with seedbed preparation by chisel plow, manual spreading of wheat seeds and without any addition of organic matter or any forming of pits.

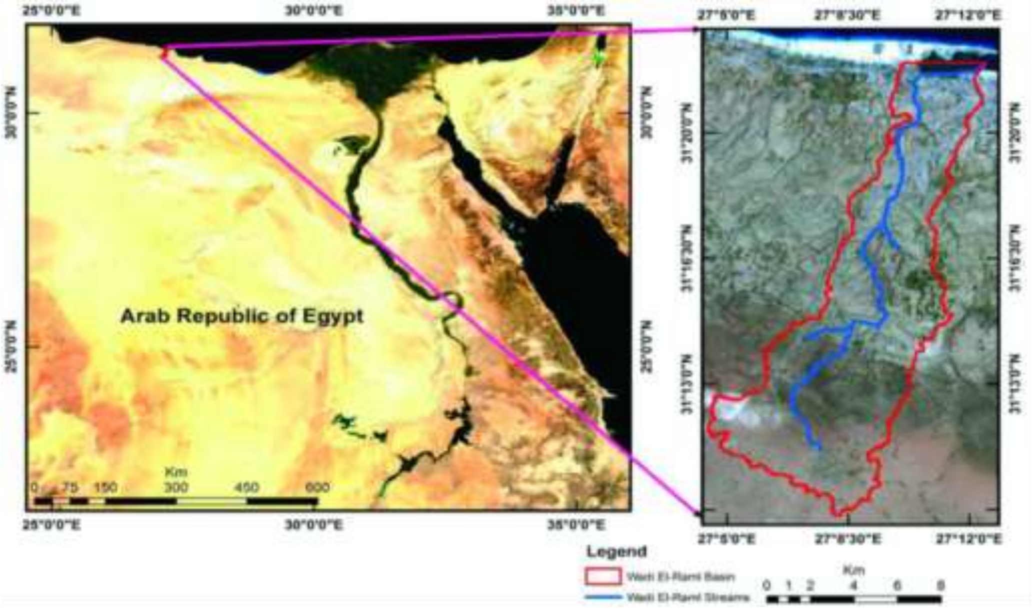

Fig. (5) The location map of the study area at northwestern Coast of Egypt.

Table (1) Physical and chemical characteristics of the soil of the study area.

Soil depth (cm)	Particle size distribution %				Texture Class	CaCO3 g kg^{-1}	O.M g kg^{-1}	pH	EC (ds/m)
	Coarse Sand	Fine Sand	Silt	Clay					
(0-20)	52.92	24.64	12.55	9.89	Sandy loam	67.8	3.1	7.72	1.21
(20-40)	48.15	24.52	17.22	10.11	Sandy loam	46	3.5	7.65	1.18
(40-60)	43.41	28.17	18.14	10.28	Sandy loam	50.2	3.6	7.46	0.99

The statistical design of the experiment

The field experiment design was a split plot with three replicates for each treatment at area of about 0.5 hectare. Main plots included two rates of farmyard manure fertilizer of 0 and 25 m^3/ha. Sub main plots included three types of pits' dimensions which were 0.50×0.14×0.20 m (PD1), 0.60×0.17×0.14 m (PD2) and 0.70×0.20×0.10 m (PD3) for length× width× depth m, respectively. All pits had the same volume about of 10.35 liters and the length of pits perpendicular on slope direction. In addition to a control treatment with three replicates of traditional cultivation method of wheat. The total experimental treatments were 21. All the study treatments were plowed in the same way using a chisel plow 7-blades at a tillage depth of 20 cm and twice perpendicular passes. Organic fertilizer was added to the experimental soil in the winter season prior to the planting season, in order to give sufficient time for the decomposition of the organic matter in the soil and thus improve the physical and chemical properties of the soil and increase its fertility. The tractor was used at a constant forward speed of 3 km/h, whether for the PRT machine or tillage operation.

Harvesting

Before harvesting wheat crop, three randomized samples were taken by hand from each plot using a wooden square frame (1 m^2) as a simpler to determine the wheat yield per feeding. Finally, the wheat crop was harvested using a mounted mower and threshing by thresher. Moisture content of wheat grain at harvesting was 12% db.

Statistical analysis

The statistical procedures were investigated by using SPSS version 19 (SPSS Inc., Chicago, Illinois, USA).

Measurements

Theoretical and actual field capacities and field efficiency

The theoretical and actual field capacities and field efficiency were calculated by the equations according to [17] as follows:

a. Theoretical field capacity:

$$\mathbf{TFC} = (\mathbf{S} \times \mathbf{W}) / \mathbf{10}$$

Where: $\mathbf{TFC} =$ Theoretical field capacity, ha/h, $\mathbf{S} =$ Operation speed of PRT machine, km/h and $\mathbf{W} =$ operational width of PRT machine, m. Whereas the operational width of machine changed as 1.59m, 1.62m and 1.65m with changing digging blades width as 0.14, 0.17 and 0.20 m, respectively.

b. Actual field capacity:

$$\mathbf{AFC} = (\mathbf{Apx3600}) / (\mathbf{Tpx10000})$$

Where: $\mathbf{AFC} =$ Actual field capacity, ha/h, $\mathbf{A_P} =$ Plot area (width × length), m^2 and $\mathbf{T_P} =$ Actual time required for conducting operation processes on plot area, s.

c. Field efficiency

Field efficiency is the ratio of actual field capacity to the theoretical field capacity, expressed as percentage. It was calculated as follows:

$$\mathcal{E}_f = (\mathbf{AFC} / \mathbf{TFC}) \times \mathbf{100}$$

Where: $\mathcal{E}_f =$ Field efficiency, %.

Filling efficiency of Pits

Actual volume of formed pit was estimated by covering the inside of the pit with thin plastic and then filling it completely with water, then measuring the volume of water by using graduated cylinder. The efficiency of pits filling was calculated as follows:

$$\mathcal{E}_i = (\mathbf{Va} / \mathbf{Vt}) \times \mathbf{100}$$

Where: $\boldsymbol{\varepsilon}_\mathbf{i} =$ Filling efficiency of Pits, %, $\mathbf{V_a} =$ Actual volume of pit formed by PRT machine, l and $\mathbf{V_t} =$ Theoretical volume of standard pit which equals 10.35 l.

Overall efficiency

As both field efficiency ($\boldsymbol{\varepsilon_f}$) and filling efficiency of pits ($\boldsymbol{\varepsilon_i}$) are influencing the final results and to express this influence, an overall efficiency is estimated as follows:

$$\boldsymbol{\varepsilon}_\mathbf{o} = \boldsymbol{\varepsilon}_\mathbf{f} \times \boldsymbol{\varepsilon}_\mathbf{i} \times \mathbf{100}$$

Where: $\boldsymbol{\varepsilon_o} =$ Overall efficiency, %, $\boldsymbol{\varepsilon_f} =$ Field efficiency, % and $\boldsymbol{\varepsilon_i} =$ Filling efficiency of Pits, %.

Pulling force

It was measured by coupling hydraulic dynamometer between two tractors with attaching the PRT machine to estimate its draught force. It was taken the average of 10 readings of the draught force at 10 second intervals [14].

Fuel consumption rate

It was measured by using the fuel meter as shown in **Fig. (4**) according to [15]**.**

Surface runoff

The runoff volume and soil loss were measured by using Troughs that were installed in auger holes at the down-slope edge of each plot to receive and collect rainwater runoff and sediment. These troughs were covered so that rainwater could not enter, and evaporation was assumed to be negligible. The runoff volume was determined from the measured depth of water in each trough.

Soil loss

Soil loss (sediment) was collected with the runoff and filtered by dry filter papers, then dried the filter papers at 60 °C for 24 h and weighed by high-precision (0.001 g) scales. Soil loss rate was defined by dividing sediment weight per unit area.

Both surface runoff and soil loss were measured once in each cultivation season at the down-slope edge of each plot.

Crop yield

It included both wheat grain and straw yields, Mg ha^{-1}.

Operation Costs

The hourly costs of tractor, chisel plow and PRT machine were calculated according to the well-known conventional method of estimating both fixed and variable costs for each implement according to [18] under some assumptions as shown in **Table (2)** as follows:

Table (2) Values of the calculation parameters of tractor, chisel and PRT machine.

Assumption	Tractor	Chisel plow	PRT machine
	Fixed costs		
purchase price, EGP	750000	15000	75000
Salvage value*	10% the purchase price		
Average annual use*, h	1000	300	500
Average lifespan*, h.	15000	2400	2500
Interest rate*, %	12		
Insurance, housing and taxes*	3% of purchase price per year.		
	Variable costs (EGP/h)		
Fuel price in 2021, EGP	6.75		
Lubrication cost*, EGP	30% of the fuel cost	80% of fixed costs*	
Repair and maintenance *	4.5% of total cost price		
Labor charge EGP/day	200		

The values marked by * in **table 1** refer to standard data according to [19].

Total costs

$$\mathbf{TC} = (\mathbf{Fixd\ costs} + \mathbf{variable\ costs}) \times \mathbf{1.10}$$

Where: **TC** = Hourly total cost for tractor or chisel plow or PRT machine, EGP/h.

- **For ploughing process**
  It included the operational cost of tractor and chisel plow.

- **For planting and reservoir tillage processes**
  It included the operational cost of tractor and PRT machine.

Total cost per unit area:

Total cost per unit area was determined according to [20] as follows:

$$\mathbf{TCA} = \mathbf{TC/AFC}$$

Where: **TCA** = Total operational cost per unit area, EGP/ha, **AFC** = Actual field capacity, ha/h and **TC** = Hourly total cost, EGP/h.

Net profit:

It was estimated as follows:

$$\mathbf{NP} = \mathbf{TR} - \mathbf{TCA}$$

Where: **NP** = Net profit, EGP/ha and **TR** = Total revenue, EGP/ha.

3. Results And Discussion

Actual field capacity

As shown in **Fig. 6** the results indicated that actual field capacity increased about of 5.13% when adding farmyard manure to the soil compared to not adding it. This may be due to the fact that adding organic fertilizer to the soil improves its physical and chemical properties, improves soil aggregates and reduces its resistance to the machine's blades. Therefore, the wasted work time can be reduced, so the actual field capacity of the machine increases, this is in agreement with [15] and [21].

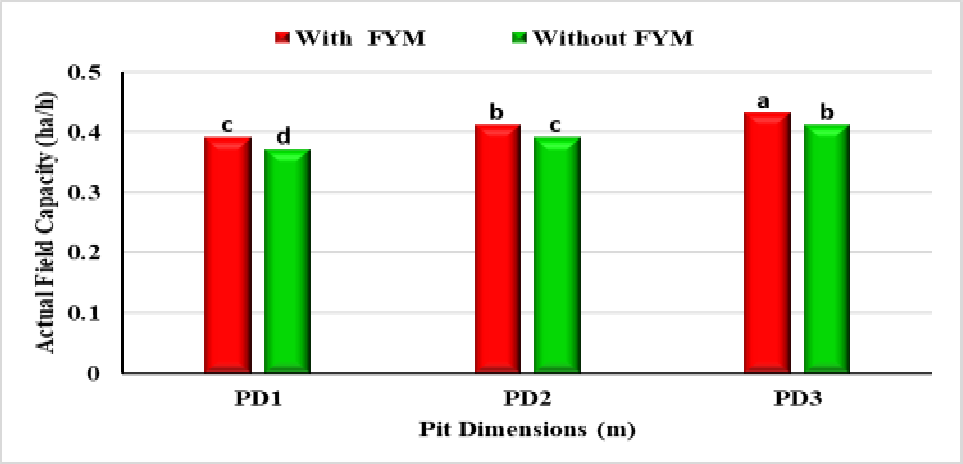

Fig. (6) Effect of treatments on actual field capacity (ha/h). Values followed by different letters are significantly at $p < 0.05$ and L.S.D = 0.0064.

On the other hand, the results showed that actual field capacity decreased as the pit depth increased. whereas the actual field capacity decreased by about 4.76% and 9.52% at the pits' dimensions PD2 and PD1, respectively compared to the pit dimension PD3. This may be due to the fact that the pit with smaller surface area and greater depth increases the soil resistance facing the machine diggers, so the required operational time increases which reduces the actual field capacity, and this is in agreement with [2], [22], [23]and [24]. The results generally indicated that there were significant effects of the treatments on actual field capacity at a significance level of 0.05. Therebefore, it is clear that the greatest actual field capacity value was achieved at pit dimensions of PD3 with adding farmyard manure. While the lowest actual field capacity was obtained at pit dimensions of PD1 without adding farmyard manure.

Field efficiency

Data in **Fig. (7)** showed that field efficiency increased about of 5.13% when adding farmyard manure to the soil compared to not adding it. The main reason for this result may be that as a result of the increase of actual field capacity, the field efficiency also increases, this is in agreement with [21]and [25].

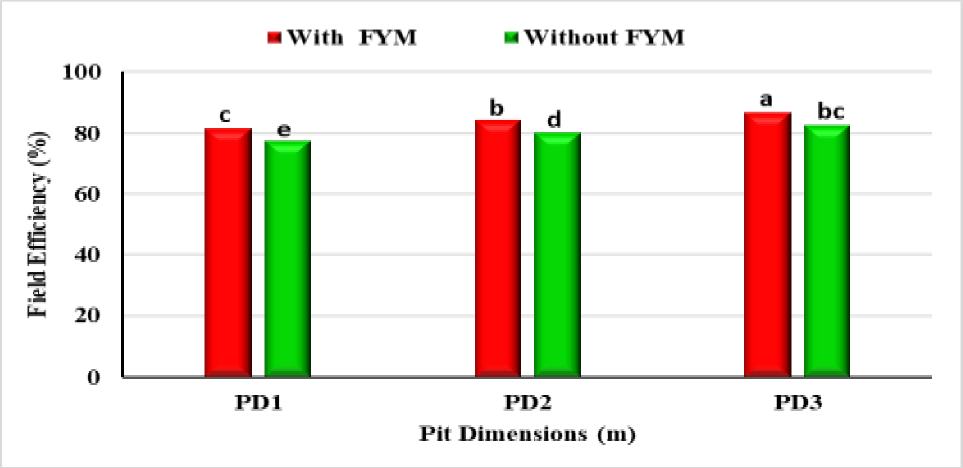

Fig. (7) Field efficiency values (%) followed by different letters are significantly at $p < 0.05$ and L.S.D = 1.5373

On the other hand, the results showed that field efficiency increased as the pit depth decreased. Whereas the field efficiency decreased by about 3% and 6.11% at the dimensions of the pit PD2 and PD1, respectively compared to the dimension PD3 m. This may be because the fact that the pit with greater depth increases the soil resistance facing the machine digger, which causes an increase of the actual operational time and the lost time. Therefore, actual field capacity reduces, subsequently field efficiency reduces, and this is in agreement with [2], [23] and [24]. The results generally indicated that there were significant effects of the treatments on field efficiency at a significance level of 0.05. Finally, it is clear that the greatest value of field efficiency was achieved at pit dimensions of PD3m with adding farmyard manure. While the lowest value was obtained at pit dimensions of PD1 m without adding farmyard manure.

Filling efficiency of pits

The results indicated that the filling efficiency of pits increased by about of 9.17% when adding farmyard manure to the soil compared to not adding it as shown in **Fig. (8**) This can be explained by the fact that adding farmyard manure improves the soil physical properties and increases its content of organic matter, which increases its ability to retain moisture. This improves the efficiency of pit formation and makes it more resistant to collapse, thus the filling efficiency of pits increased, this is in agreement with [14] and [25].

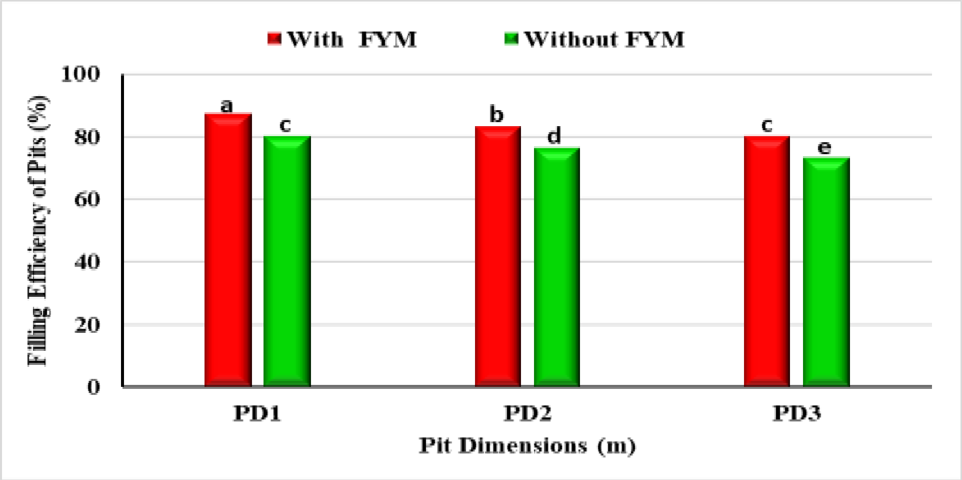

Fig. (8) Filling Efficiency of pits values (%) followed by different letters are significantly at $p< 0.05$ and L.S.D = 0.7686.

On the other hand, the results revealed that the filling efficiency of pits increased as the surface area of the pit decreased, and its depth increased. Whereas the filling efficiency of pits increased by about 3.92% and 9.15% at the dimensions of the pit PD2 and PD1, respectively compared to the pit dimension of PD3. The main reason for this is by increasing the digging depth, the soil bulk density increases, so higher proportion of small diameter pores increases in the soil and consequently, greater cohesion forces and compaction between the soil grains increased. Thus, the pits that have smaller surface areas and greater depths are more resistant to collapse over time and have the ability to conserve their shapes better than the pits that have greater surface areas and smaller depths, and this corroborates with [2] and [25]. The results generally indicated that there were significant effects of the study treatments on filling efficiency of pits at a significance level of 0.05**.** The obtained results illustrated that there were significant effects of the study treatments on the filling efficiency of pits at a significance level of 0.05. Finally, it is concluded that the greatest value of filling efficiency of pits was achieved at pit dimensions of PD1m with adding farmyard manure. While the lowest value was obtained at pit dimensions of PD3 m without adding farmyard manure.

Overall efficiency

The results indicated that the filling efficiency of pits increased by about 14.79% when adding farmyard manure to the soil compared to not adding it as shown in **Fig. 9**. This can be explained by the fact that adding farmyard manure improves the soil physical and chemical properties and increases its content of organic matter. This increases both field efficiency and filling efficiency of formed pits, thus the overall efficiency of pits increases, this is in agreement with [14] and [25]

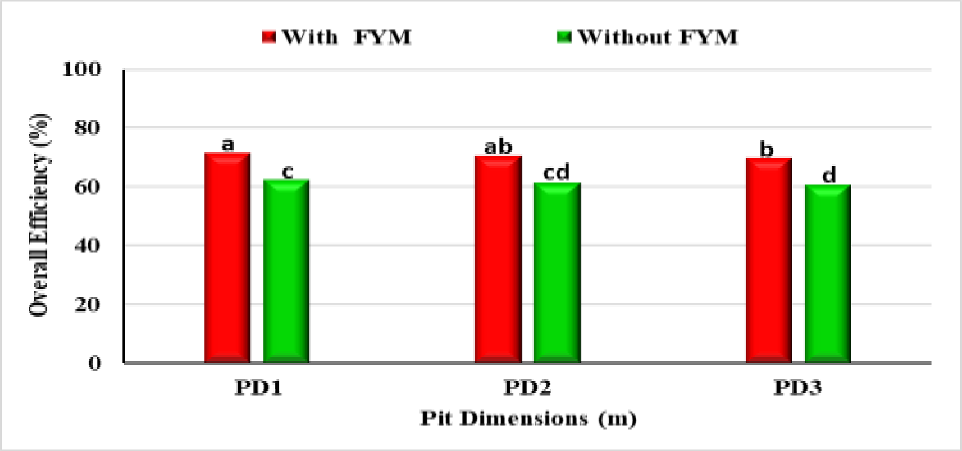

Fig. (9) Overall efficiency (%). Values followed by different letters are significantly at p< 0.05 and L.S.D = 1.1908.

On the other hand, the results illustrated that the overall efficiency increased as the surface area of the pit decreased, and its depth increased. Whereas the overall efficiency of pits increased by about 0.81% and 2.48% at the dimensions of the pit PD2 and PD1, respectively compared to the pit dimension of PD3. The main reason for this is despite the decrease of the field efficiency by decreasing the surface area of pit and increasing its digging depth, the filling efficiency of pits increases. Whereas the increase rate of filling efficiency is greater than the decrease rate of the field efficiency, so the overall efficiency increases, and this corroborates with [25]. The results generally indicated that there were significant effects of the study treatments on the overall efficiency at a significance level of 0.05**.** Finally, it is revealed that the greatest value of overall efficiency of pits was achieved at pit dimensions of PD1m with adding farmyard manure. While the lowest value was obtained at pit dimensions of PD3 m without adding farmyard manure.

Pulling force and Fuel consumption by PRT machine

The results as shown in **Figures 10** and **11** proved that pulling force and fuel consumption of PRT machine decreased by about of 26.5% and 37.54% at adding farmyard manure to the soil compared to not adding it. This may be because the fact that adding organic fertilizer to the soil improves its physical and chemical properties and soil aggregates which makes the soil more brittle in such a way that reduces its resistance to the machine's blades. Therefore fuel consumption and pulling force can be reduced this is in agreement with [14], [21] and [25]**.**

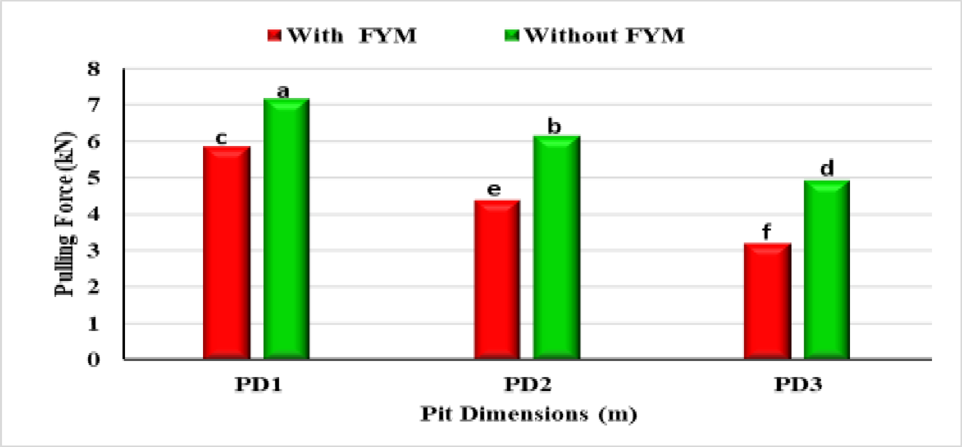

Fig. (10) Influence of treatments on pulling force (kN). Values followed by different letters are significantly at p < 0.05 and L.S.D = 0.0434.

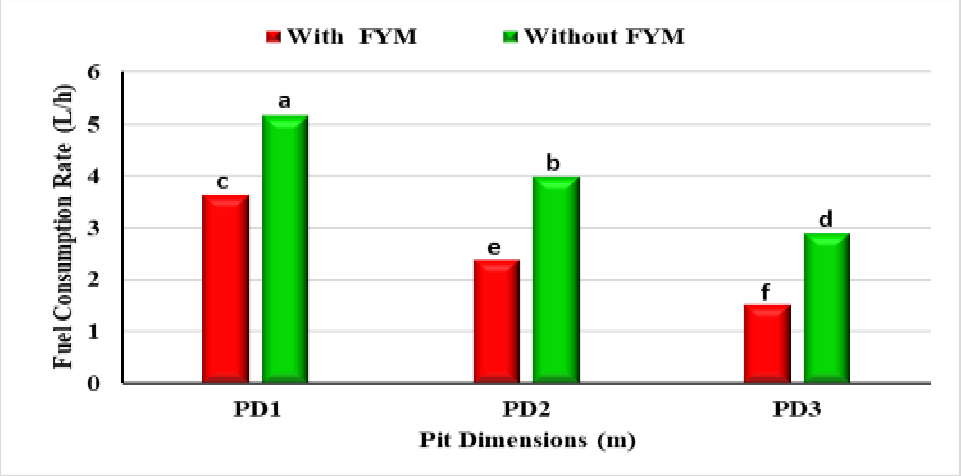

Fig. (11) Influence of treatments on fuel consumption (L/h). Values followed by different letters are significantly at $p < 0.05$ and L.S.D = 0.0133.

On the other hand, the results showed that the pulling force and fuel consumption increased as the pit depth increased. whereas pulling force and fuel consumption increased by about 29.79% and 44.55% at pit dimension of the PD2 and by about 60.32% and 100% at pit dimension of PD1, respectively compared to the dimension PD3. This may be because the fact that the pit with greater depth increases the soil resistance as a result of the increase of soil bulk density and compaction between soil particles as the pit depth increases. Thus, it requires greater pulling force which requires greater tractor's engine power, and consequently the fuel consumption increases, and this is in agreement with [2] and [26]. The results generally indicated that there were significant effects of the study treatments on pulling force and fuel consumption rate at a significance level of 0.05**.** Finally, it is appeared that the greatest values of pulling force and fuel consumption were achieved at pit dimensions of PD1 without adding farmyard manure. While the lowest values were obtained at pit dimensions of PD3 with adding farmyard manure.

Surface runoff

The average depth of rainfall per each effective rainstorm event during 2021-2022 is shown in **Fig (12**) The total annual rainfall reached 185 mm.

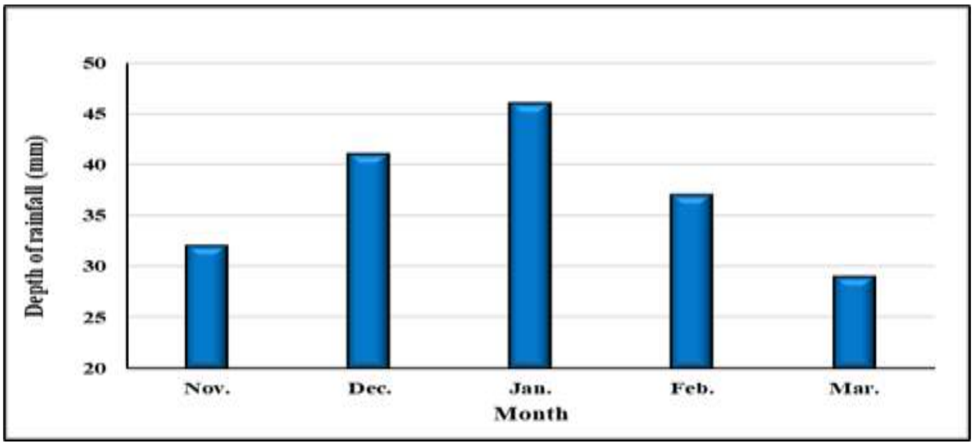

Fig. (12) The average depth of rainfall per each effective rainstorm event during 2021-2022.

As shown in **Fig. (13)** which indicates to the influence of adding the farmyard manure to the soil, the results proved that it had a positive effect of decreasing the surface runoff by about 28.53% compared to without addition FYM. This is because adding the FYM to the soil causes an increase of the filling efficiency of the pits in such a way that increases the quantity of rainwater which can be captured and stored by the pits and decreases the surface runoff of rainfall. This is in agreement with [13].

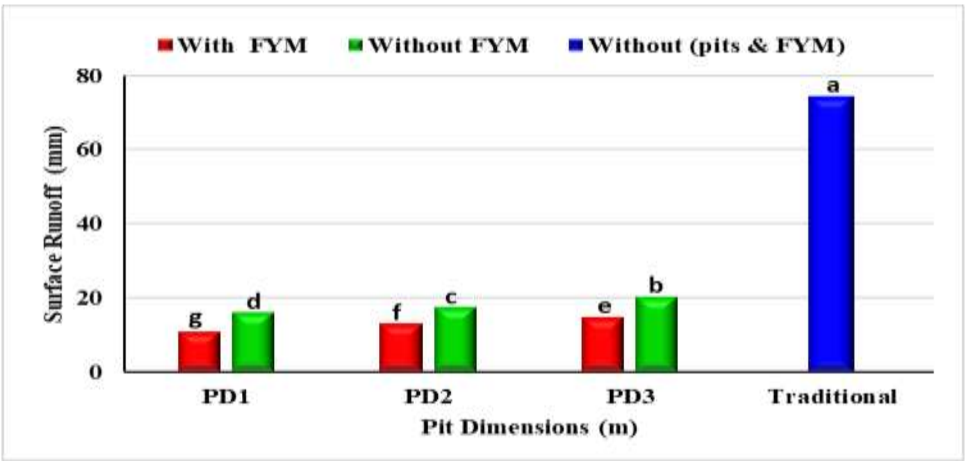

Fig. (13) Effect of study treatments on surface runoff (mm). Values followed by different letters are significantly at $p < 0.05$ and L.S.D = 0.1413.

The results illustrated that the surface runoff decreased as the surface area of the pit decreased and its depth increased, where the surface runoff decreased by about 13.22% and 22.97% at the dimensions of the pit PD2 and PD1, respectively compared to the pit dimension PD3. The reason for this is the soil bulk density increases as the digging depth of the pit in the soil increases, due to the increase in cohesion forces and the compaction between the soil particles. Therefore, the pit could conserve its shape without collapsing over time, so the rainwater could percolate into the pits instead off losing by runoff. Thus, the surface runoff decreased, and the runoff efficiency decreased by consequence which in turn is directly proportional to the surface runoff, and this corroborates the results of many other studies [2] and [14]. The results generally indicated that there were significant effects of the treatments on the surface runoff at a significance level of 0.05. The obtained results referred that the most efficient treatment that achieves the least value of the surface runoff was at the pit dimensions PD1 and with the addition of farmyard manure. Contrary to this, the greater value of the surface runoff was obtained at the pit dimensions PD3 without addition of farmyard manure. Comparing the results of the previous treatments of the machine with the traditional cultivation, it was found that all the PRT machine's treatments were the most efficient. Whereas they proved their effectiveness of reducing surface runoff particularly under using the PRT machine at pit dimensions of PD1with adding FYM which achieved a reduction by about 85.68%. This is because the traditional cultivation treatment was carried out on flat soil, without adding any organic matter or any soil formation. Therefore, there were no pits to impede the movement of rainwater falling on the sloping soil, thus the speed of rainwater runoff was increased, so it was lost, this is in agreement with [14].

Soil loss

As shown in **Fig (14)** which indicates to the effect of adding the farmyard manure to the soil. The results illustrated that adding it to the soil reduced the soil loss by about 24.74% compared to without any addition. This is because the rainwater surface runoff decreased with adding farmyard manure to the soil, and this is in agreement with [13] and [27].

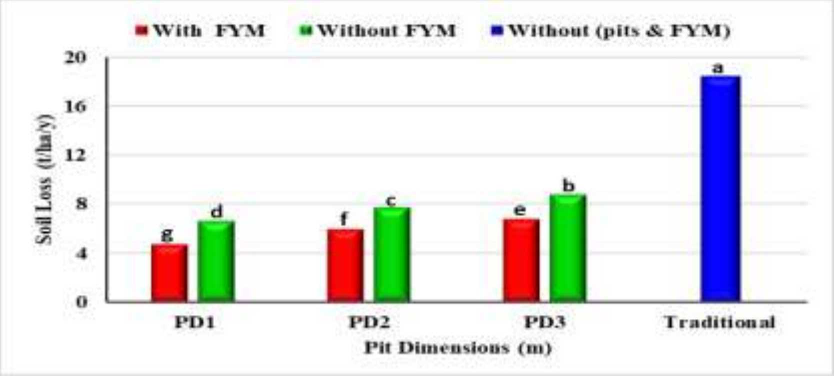

Fig. (14) Effect of study treatments on soil loss (t/ha/yr.). Values followed by different letters are significantly at $p < 0.05$ and L.S.D = 0.0467.

The results showed that the soil loss decreased as the surface area of the pit decreased and its depth increased, where the soil loss decreased by about 12.17% and 27.38% at the dimensions of the pit PD2 and PD1, respectively compared to the dimension PD3. This occurred because soil loss decreases as the surface runoff decreases, which in turn decreases as the digging depth of the pit in the soil increases due to greater pit capacity, and this is in agreement with [2] and [14]. The results generally indicated that there were significant effects of the treatments on the soil loss at a significance level of 0.05. The obtained results referred that the most efficient treatment that achieved the least value of the soil loss was at pit dimensions of PD1 and with the addition of farmyard manure. Contrary to this, the greater value of the soil loss was obtained pit dimensions of PD3 and without addition of farmyard manure. For comparing all treatments of the PRT machine with the traditional cultivation treatment, it was found that all treatments of the PRT machine decreased values of soil loss particularly at pit dimensions of PD1 with addition of FYM which decreased the value of soil loss by about 74.76% compared to the traditional cultivation. This was because the traditional cultivation treatment was carried out on flat soil, without adding any organic matter or any catchment areas of fallen rainwater on the sloping soil which increases the speed of rainwater runoff, so it can be lost, this is in agreement with [28].

Wheat grain and straw yield.

The results as shown in **Fig (15** and **16)** indicates the effect of adding the farmyard manure to the soil, it was found that adding it to the soil increased the wheat yield by about of 19.16% and 17.44% for grain yield and straw yield, respectively, compared to without addition treatment. This is because the fact that decomposed farmyard manure increases the activities of microorganism which improves the soil physical properties of its structure. Thus, the soil becomes more brittle by promoting the soil aggregates assembling that enable roots to grow and penetrate into the soil easily and rapidly. Moreover, farmyard manure is a potentially important source of N, P, K and other micro-nutrients. FYM supplies all major nutrients, necessary for plant growth with respect to increasing yield. The improving effect of the applied organic fertilization (FYM) is on soil structure, the water holding capacity of the rooting medium and consequently on the availability of the nutrients, which reflect on the wheat yield and its productivity, and this is in agreement with [13] and [27].

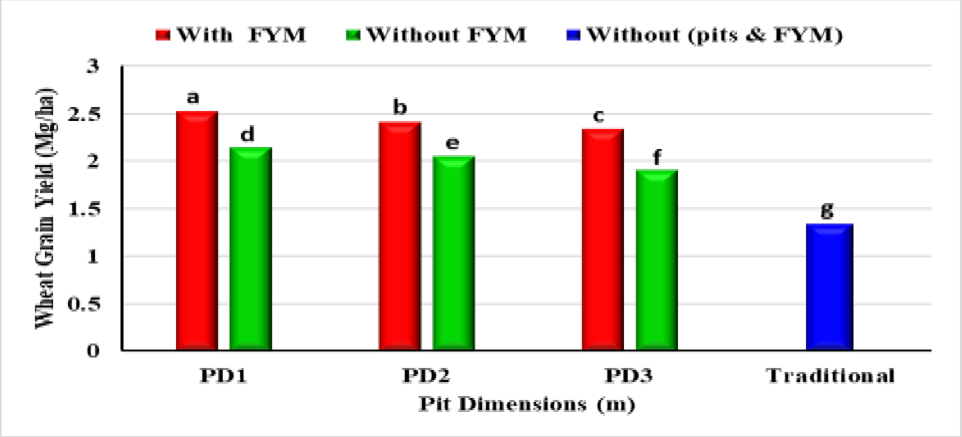

Fig. (15) Effect of study treatments on wheat grain yield (Mg/ha). Values followed by different letters are significantly at $p < 0.05$ and L.S.D = 0.0729.

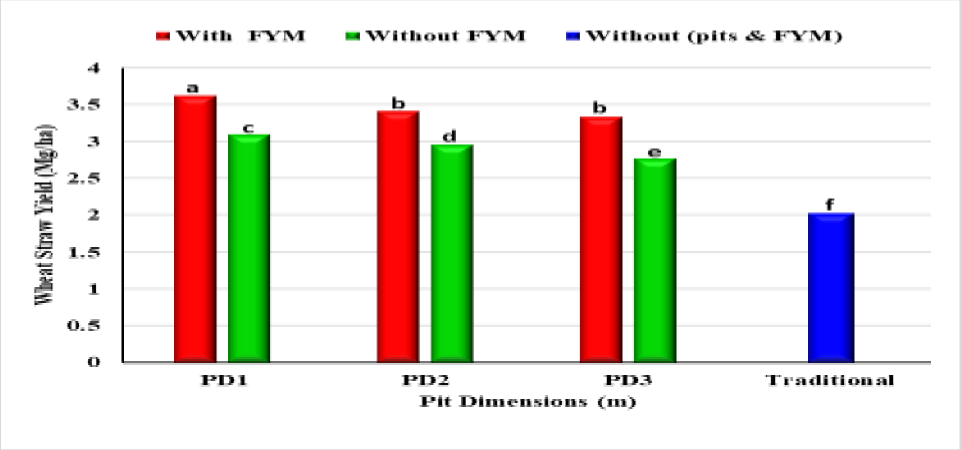

Fig. (16) Effect of study treatments on wheat straw yield (Mg/ha). Values followed by different letters are significantly at $p < 0.05$ and L.S.D = 0.1248.

On the other hand, the results illustrated that the wheat yield increased as the surface area of the pit decreased and its depth increased, where the wheat grain yield increased by about 5.12% and 9.89% for grain yield and 4.46% and 10.03% for straw yield at the dimensions of the pit PD2 and PD1, respectively compared to the dimension PD3. This is due to the increase of pit filling efficiency and decreased rainwater runoff which caused increasing the soil moisture storage as a water requirement for wheat crop. this is in agreement with [14] and [29]**.** The results generally indicated that there were significant effects of the treatments on the wheat yield included grain yield and straw yield at a significance level of 0.05**.** The obtained results referred that the most efficient treatment that maximized the wheat yield productivity was at pit dimensions of PD1 and with the addition of FYM. Contrary to this, the least value of wheat productivity was obtained pit dimensions of PD3 without any addition of FYM. For comparing all treatments of the PRT machine with the traditional cultivation treatment, it was found that all treatments of the machine achieved the greatest values of wheat yield including grain yield and straw yield. Whereas they proved their effectiveness of increasing wheat productivity particularly under using the PRT machine at pit dimensions of PD1 with addition of FYM due to achieve an increase by about 88.44% and 79.69% for grain and straw yields, respectively compared with traditional cultivation. This is because the traditional cultivation treatment was accomplished on flat soil without adding any organic matter or any pits formation which increases soil bulk density and enhanced soil compaction. This causes a lack of soil moisture storage by losing the fallen rainwater by surface runoff, and also inhibited the growth of wheat roots [30] and [31]. In contrary, all PRT machine treatments can harvest more runoff by catchment pits in the cultivated areas and efficiently conserve higher soil water storage during wheat growth, thereby promoting wheat crop growth and increasing grain and straw yield, this is agreed with [14], [32] and [33].

Net profit of Wheat crop productivity

The results as shown in **Fig. 17** indicated that the net profit increased by about of 8.56% when adding farmyard manure to the soil compared to not adding it. This may be due to the fact that by adding farmyard manure, the total energy requirements of operation decreased, and by consequence, the fuel consumption decreased. This leads to decrease the operation cost of the machine. Moreover, wheat yield increased with adding farmyard manure, thus the net profit increases, and this is in agreement with [34] and [35].

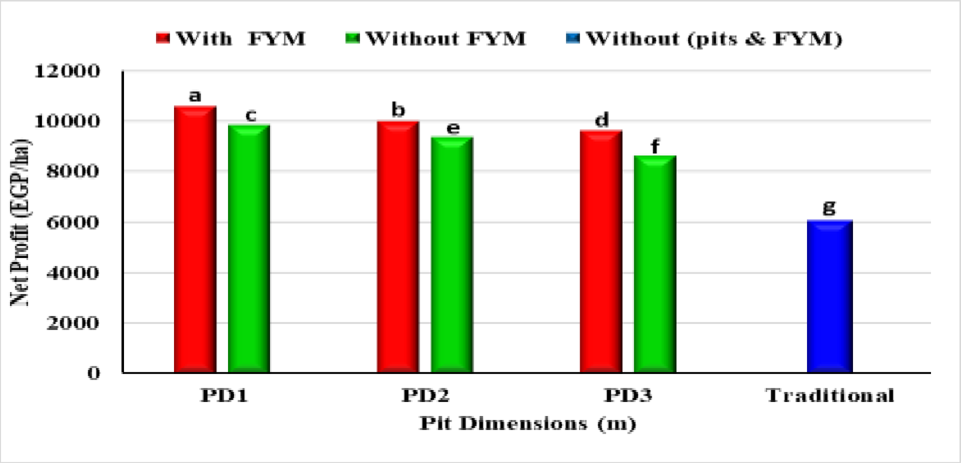

Fig. (17) Influence of treatments on net profit (EGP/ha). Values followed by different letters are significantly at $p < 0.05$ and L.S.D = 112.9.

On the other hand, the results revealed that the net profit increased as the surface area of the pit decreased, and its depth increased. Where the net profit increased by about of 6.05% and 11.95% at the pit dimensions of PD2 and PD1, respectively compared to the dimension PD3. This is due to the increase of the wheat yield that resulted from the increase of the soil moisture storage around the wheat roots at smaller surface area of the pits so, rainwater lost by evaporation to the air decreases. Moreover, the increase of the efficiency of the pits implement as the digging depth increases. This can consolidate the internal surface of the pits so that more rainwater quantity could be held to percolate into the soil with conserving their shapes for a long time, thus wheat yield increases. Therefore, the net profit increases, and this is in agreement with [14] and [34]**.** The results generally indicated that there were significant effects of the study treatments on the net profit at a significance level of 0.05. The obtained results proved that the most efficient treatment that had the greatest value of net profit was achieved at pit dimensions of PD1 and with the addition of FYM. By contrast, the least value was obtained at pit dimensions PD3 and without addition of FYM. Comparing the results of the previous treatments of the machine with the traditional cultivation, it was found that all the PRT machine's treatments were the most efficient. Whereas they proved their effectiveness of increasing the net profit particularly at pit dimensions of PD1 and with addition of FYM which increased the net profit by about 73.97% compared with traditional cultivation. This is because the traditional cultivation treatment was achieved the lowest yield of wheat crop compared to the treatments of the PRT machine, this is in agreement with [14] and [36].

4. Conclusion

The obtained results confirmed that applying the reservoir tillage system by the PRT machine with adding farmyard manure increased the soil resistance to the water soil erosion under rainfed conditions of Wadi El-Raml compared to traditional cultivation method. Moreover, using the PRT machine at pits dimensions of PD1and with addition of farmyard manure decreased the surface runoff and soil loss by about 85.67% and 74.76%, respectively, increased wheat grain and straw yields and net profit by about 88.44%, 79.69% and 73.97%, respectively, compared to the traditional cultivation treatment.

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