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Manufacturing of machine for crop cultivating under rainfed conditions

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The ridge-furrow rainwater harvesting system (RF) is an effective system of harvesting rainwater, improving rainwater use efficiency, reducing soil erosion, and increasing winter wheat productivity in arid and semi-arid regions. Despite the many benefits of (RF), it has not been scientifically evaluated like other rainwater harvesting systems in the arid and semi-arid regions of Egypt. One of the main reasons for the non-expansion (RF) system is the difficulty of implementing this system. Therefore, the main aim of this study was to manufacture a machine to carry out (RF) system by establishing ridges as areas for rainwater harvesting at the different shapes and widths of ridges surface also sowing wheat seeds in furrows between ridges. A field experiment was conducted during the 2016-2017 of the winter wheat growing season in Wadi El-Raml North Western Coast of Egypt, a field study under the following treatments: different shapes of ridge surface (horizontal, inclined in one direction, inclined in two directions and bending). Ridge-furrow ratios (30cm:50cm, 50cm:50cm and 70cm:50cm) and covered the ridges surface with different mulching material (without cover, asphalt emulsion and plastic film), while conventional flat planting (CF) was employed as the control treatment, to evaluate the effects of (RF) system at different previous treatments with performance efficiency and power requirements of the manufactured machine, runoff efficiency, soil moisture stored, wheat grain-straw yield and net profit. The study results indicated that the (RF) system at all treatments is an efficient way to enhance rainwater accessibility for wheat crop compared to (CF) system. The results showed that bending shape of ridge surface and covered ridges with plastic film performed best in increasing runoff efficiency for rain water harvesting areas (ridges), soil moisture stored in sowing areas (furrows), wheat grain-straw yield and net profit compared to another ridge-furrow system treatments. The optimum ridge width was derived at the different shapes of ridges surface horizontal, inclined in one direction, inclined in two directions and bending respectively, were 38, 42, 44 and 45cm when not covered and 45, 46, 47 and 47cm when covered with asphalt emulsion and 46, 47, 48 and 48cm when covered with plastic film.

Keywords: ridge-furrow rainwater harvesting system, wheat yield, mulching, runoff efficiency, soil moisture storage.

INTRODUCTION

Water scarcity limits the sustainable development of rainfed agriculture in arid and semi-arid regions. Crop growth and production in these regions is constrained by drought due to limited rainfall (Lv et al., 2009). This study used Egypt as the focus region because it lies in the heart of the water scarcity problem. Egypt's rainfed agriculture is mainly concentrated in the northwestern coastal zone, which extends approximately 500 km from the western city of El-Saloum on the border with Libya, to Alexandria in the east. It is bounded by the Mediterranean Sea on the north and the Sahara Desert, about 60 km to the south. This area has a unique hydrological cycle with low annual precipitation (from 130 to 150 mm). Agricultural production on rainfed farms is dependent on rainfall, and farmers are generally more concerned about the availability of water. Hence, the key to increasing agricultural productivity lies in the maximal utilization of precipitation, which requires harvesting light rainfall (Qin and Li, 2005; Qin et al., 2013). Therefore, water management practice must be aimed at fully enhancing the efficiency of the limited water being used (Shan and Xu, 1991). In recent decades, there has been increased interest in the evaluation of traditional water management techniques (Prinz and Wolfer, 1999; Salem et al., 2015), such as rainwater harvesting for drylands agriculture, which aims to ease future water scarcity in many arid and semi-arid regions of the world.

Rainwater harvesting based on the collection and concentration of surface runoff for cultivation has been practiced in different parts of the world for thousands of years (Reiz et al., 1988). Water harvesting is a method of collecting surface runoff from a catchment area and storing it in surface reservoirs, or in the root zone of a cultivated area. It can be a source of water for a variety of purposes in arid and semiarid regions when common sources, such as streams, springs, or wells (Frasier, 1980). Water harvesting is the process of collecting and storing water for later beneficial use from an area that has been modified or treated to increase precipitation runoff (Frasier, 1994). The collected water can be used for most purposes such as domestic uses and for growing plants. Micro-catchment rainwater harvesting systems (MCWH) is very effective in arid and semiarid regions where irrigation water is not available or costly (Boars et al., 1994). Using MCWH accompanied with mulch increased the corn grain yield by 46.29% as compared to the cultivation in flat bare soil (Li et al., 2000). MCWH can improve soil moisture storage, prolong the period of moisture availability and enhance growth of agricultural, horticultural and forest crop (Li, 2000). To maximize the utilization of the low rainfall in the dry semiarid region a plastic-covered ridge and furrow rainwater harvesting (MCWH) system combined with different mulches was designed to collect water from the light rain (Xiao et al., 2001). As one kind of MCWH, a ridge-furrow system harvests rainwater by changing the micro-topography on a small field scale (Li et al., 2011; Tian et al., 2003), and thus it could be applied easily. Many relevant studies have shown that this micro-catchment rainwater-harvesting system could substantially improve agricultural productivity, crop yield, and water use efficiency (Oweis and Hachum, 2006; Li et al., 2011). This system can create an impermeable barrier to effectively restrict water and thermal loss, and meanwhile have the potential to increase deep-water storage in planting areas by collecting runoff from ridges and rainfall-coupled runoff in furrows (Ren et al., 2017).

Tian et al. (2003) showed that ridge-furrow rainwater harvesting (RFRH) planting pattern, with ridges mulched with plastic film that serve as the runoff area and with furrows as the infiltration or planting area, has been a useful method for improving crop productivity in arid and semi-arid areas. Deng et al., (2006) reported that ridge-furrow rainwater harvesting (RFRH) usually consists of alternate parallel ridges and furrows built along the contours on sloppy land, where the ridge is usually mulched with film for rainwater harvesting and furrow is used for crop planting without mulching. This method is one of the most efficient technical applications for maximizing the utilization of rainfall especial light rainfall, in semiarid regions. The RFRH collected runoff from ridges and rainwater coupled runoff in furrows leading to a deep soil water infiltration. Jin et al. (2010) showed that a ridge-furrow rainfall harvest system (RFRHS) could increase the efficiency of rainfall. Qin et al., (2014) showed that potato yield was increased by 36.3% with RFRH, while the water use efficiency (WUE) was increased by 33.5% compared with conventional flat cultivation. Patrick et al. (2004) recommend that water scarcity during the critical growth stages (flowering and grain filling stage) of wheat can be reduced by the ridge-furrow (RF) system as a result improve total dry matter and grain yield in semiarid regions. Abbas et al., (2005) mention that the ridge-furrow (RF) micro-rainfall collecting system has been extensively established in semiarid regions. The (RF) planting model includes a rainfall collecting zone (ridge) and sowing zone (furrow) which improve precipitation use efficiency. Jia et al., (2006) showed that the (RF) system combined with plastic film mulching can increase the soil water availability for crops by collecting water from low intensity rainfall events, and preserve surface runoff during heavy precipitation thereby facilitating sustainable farming productivity and high water use efficiency (WUE) in semiarid areas of the world. Ren et al., (2008) reported that ridges and furrows are alternated in the rainfall concentration system

(RC), where the ridges are mulched with rain harvesting materials and the furrows are planted with crops. The relationships and interactions among the furrows and ridges comprise a system that regulates the water environment to meet the needs of crop growth and that exploits the full production potential of precipitation. Zhou et al. (2009) found that (RFRHS) could increase soil surface temperature and prolong the growth period. Optimum ridge-furrow ratio depends on several factors, including precipitation characteristic, soil type, crop species, land topography, and climate (Wang et al., 2005; Li et al., 2007; Li et al., 2008; Gan et al., 2013; Li et al., 2019). Zhou et al., (2015) since the early 1990s, several cheaper and more effective technologies, including plastic film mulching and rainwater harvesting strategies, have been widely developed and applied in semiarid, agroecosystems. Wang et al., (2015a) one innovative water-saving technology, called the ridge-furrow with plastic film mulching (RFPFM) system, has been developed to drastically increase the precipitation use efficiency in rainfed farming systems in arid and semiarid areas worldwide.

The ridge-furrow mulching system (RFMS) is one of the innovative water saving technologies which aim to drastically increase the precipitation use efficiency in rainfed farming systems in arid and semi-arid areas (Li et al., 2006; Gu et al., 2016; Li et al., 2016). In this system, the mulched hemispherical ridges are used for collecting runoff and serve to be a rainwater harvesting zone, while mulched or non-mulched furrow serve to be a planting zone, resulting in deeper water penetration and reduce water loss-evaporation and soil erosion (Zhou et al., 2009; Gan et al., 2013; Li et al., 2017). Li et al., (1999) showed that in order to increase the efficiency of the harvested water, the plastic film was used to cover the ridges (or runoff areas). Tian et al., (2003) reported that the range in runoff efficiency (RE) was 1 to 27% of bare ridge treatments and 31 to 93% of mulched ridge treatments of the ridge -furrow system. Li and Zhang (2005) reported that rainfall, over 0.8 mm, could generate runoff on the plastic-covered ridge and was accumulated in the furrows. It was very useful in semiarid condition, which had too many small and useless rainfall. Studies about corn, potato, spring wheat and alfalfa had shown that there was a considerable increase in yield (Li et al., 1999, 2001, 2007; Tian et al., 2003). Wang et al., (2008) reported that the great success of (RF) system in different regions of the world is mainly because of the better collection of light or heavy rain driven by ridges-furrows effect that leads to a high runoff efficiency of precipitation. The (RF) for plastic mulched ridge treatments was higher than that for bare ridge treatments because of the plastic film's smooth, nonleaking surface. Mudatenguha et al., (2014) stated that combined with mulching and ridge-furrow planting, ridge-furrow planting with plastic film mulched ridges (RFPR) has been developed, where the ridge serves as a rainwater harvesting zone and the furrow serves as a planting zone. Carter and Miller (1991) showed that (RFPR), especially the ridge-furrow planting with plastic film mulched ridges and crop straw mulched furrows, can further prevent soil water loss and enhance rainwater harvesting ability. Hu et al. (1997) mention that the (RFMH) system can collect water, aid water permeation, improve the root systems moisture level and hence remarkably elevate crop production in semiarid and drought-inclined areas. The result showed that mulching ridges with narrow furrows is better than mulching ridges with wide furrows. Therefore, choosing the optimum ridge-furrow ratios and suitable ridge-covering materials are of great importance to the development of a more effective (RFMH) system. In order to make effective use of light and heavy rain, choosing appropriate ridge-furrow ratio plays a critical role in the development of more effective (RFMS) systems (Wang et al., 2015b). Gan et al., (2013) found that crop yield under a ridge-furrow system for harvesting rainwater increased by 10%-40% in comparison with conventional flat planting. Wu et al., (2015) reported that the (RFPR) can prolong the period of soil water availability by doubling the amount of precipitation collected in the plant furrows, which allows a better use of light rains (<5 mm), and can attain a rainwater collection efficiency of 87%. Li et al. (2016) proved that ridge-furrow system for harvesting rainwater increases water use efficiency of wheat crop 53.7%.

Therefore, the main objective of this research was to manufacture a machine for rainwater harvesting and sowing of wheat crop by the ridge-furrow system with the formation of the ridge surface in a way that increases their efficiency as rainwater harvesting areas. Therefore, this study work to currency this system in the dry areas so that the inhabitants of these areas can benefit from the advantages of this system to raise the rain water use efficiency for sowing winter crops, especially wheat.

MATERIALS AND METHODS

A field experiment was carried out in Wadi El-Raml basin. This basin occupies an area of about 144.35 km^2 and is located at the west of the Marsa Matrouh city in Egypt's northwestern coastal zone (latitude: between 31° 09' 20'' - 31° 21' 58'' N, and longitude: between 27° 04' 27''- 27° 12' 30'' E). The location of the study area is presented in **Figure (1**). The field experiment was carried out in the winter season of 2016-17 with an experimental area of about (one ha). The soils of Wadi El-Raml are mainly sandy loam in texture. The climatic conditions from the Marsa Matruh meteorological station (latitude 31° 20' N, longitude: 27° 13' E, and an altitude of 28 m above sea level) were used to determine the meteorological data of the study area. The arid Mediterranean climatic conditions in the study area are characterized as short rainy seasons during October–March; about 85% of the total annual rainfall is recorded between December and February. Analyses of soil and some physical and chemical characteristics were carried out according to (Klute, 1986). These analyses are presented in **Table (1).**

Table 1: Physical and chemical properties of the investigated soil.

Soil depth (cm)	Particle size distribution %				Texture class	$CaCO_3$ %	O.M %	pH	EC (ds/m)
	Coarse sand	Fine sand	Silt	Clay					
0-20	52.95	24.61	12.55	9.89	Sandy loam	6.78	0.31	7.72	1.21
20-40	48.29	24.27	17.32	10.12	Sandy loam	4.6	0.35	7.65	1.18
40-60	43.41	28.17	18.14	10.28	Sandy loam	5.02	0.36	7.46	0.99

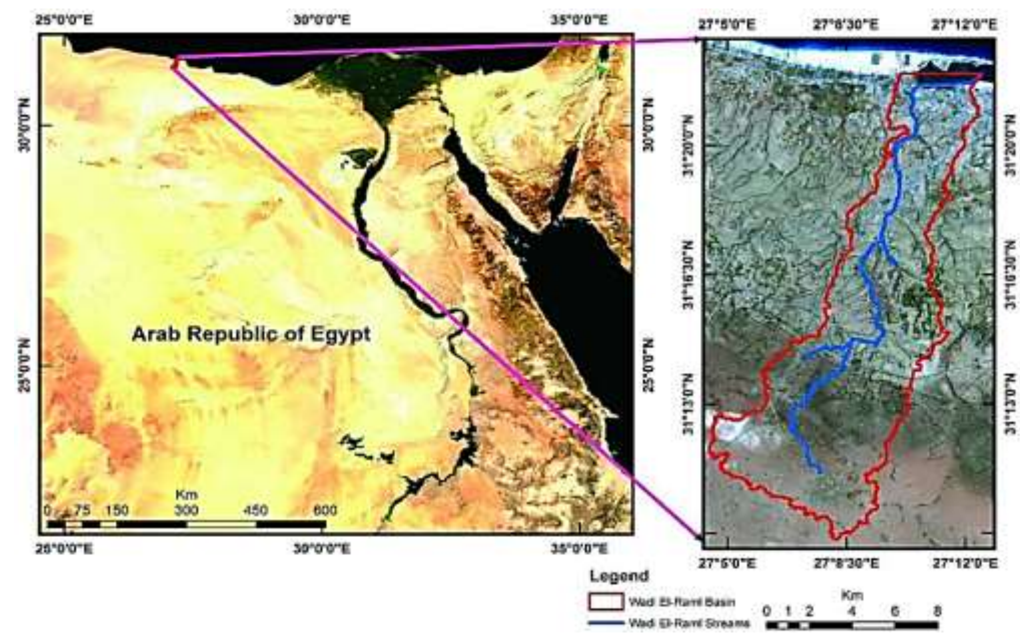


Figure 1: The location map showing the target study area at NWCZ of Egypt

The specifications of study machine:

The machine in this study was used to carry out ridge-furrow system and sowing the wheat seeds in the furrows as shown in Figure (2) photographic view and Figure (3) sketched back and side views. It is a mounted machine hitched to the tractor using the three points hitching system. The machine components were manufactured locally. The total weight, length, width and height of the machine were about of 517 Kg, 2500 mm, 1600 mm and 1700 mm respectively. The machine consisted of the frame manufactured from 100 mm L shapes iron, a three point hitching system manufactured from 20mm thickness iron at the height of an upper hitch point of 600mm and lower hitch point spread of 650mm, seed hopper made of iron sheet with a thickness of 2 mm at the maximum capacity about 60 Kg of wheat seed, two border units made of iron sheet, with a thickness of 4 mm for building the ridges at different widths. In addition to, forming the surface of ridges with different shapes of horizontal, inclined in one direction, inclined in one direction and bending, three diggers with three shanks (20 mm thickness and 70 mm width) to dig the furrows between ridges and seed metering mechanism in this seeder gear wheel type made of Teflon material. The feed wheel diameter is of (80 mm), thickness of (25 mm). The seeder width consists of eight discs divided onto four discs in the middle and two discs for each side. Each disc case has two holes the top is used as entry seed from the hopper to the disc cells, while the bottom hole is used as the exit the seeds from the disc cells to the seeds planting tube and by consequently in the furrows between ridges. The disc cells were equipped with the moving shaft in the iron case by means of a collecting unit. Transmission system was designed to transmit the motion from the ground wheel to the shaft of the feed disc through a sprocket gears to give the equivalent rotation number related to the peripheral speed of the ground wheel.

The Method of changing the shape of ridge surface:

The shape of the ridge surface was changed by using parts made from galvanized iron sheets fixed at the back of the border units as shown in Figure (4).

Change operation width of the machine at the different (ridge: furrow) ratios:

The operating width of the machine varies by changing the ratio between the ridge width and the furrow width as shown in Figure (5). Where the operating widths of the machine were 160 cm, 200 cm and 240 cm at the (ridge: furrow) ratios (30 cm: 50 cm), (50 cm: 50 cm) and (70 cm: 50 cm), respectively. Note that the operating width of the machine when used it for wheat cultivation on flat soil is equal to 100 cm.

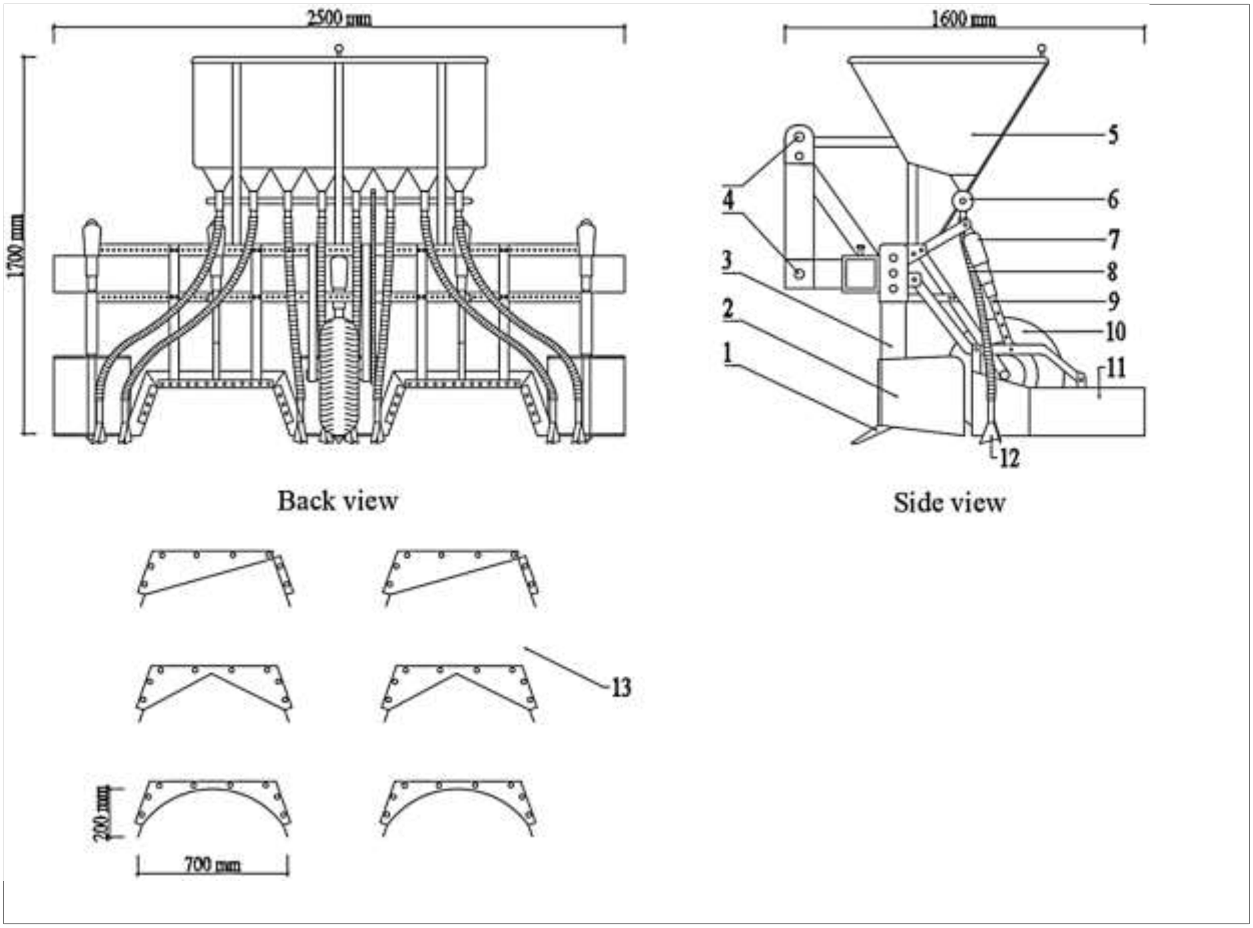
Specifications of tractor:

Specifications of the tractor were illustrated in Table (2):

Table (2): Specifications of tractor

Tractor New Holland Diesel engine - Model	4x4TT4.90
Net rated power	90 hp at 2300 rpm
Number of cylinders	4 cylinders
Weight, kg	3000
Power take-off shaft	540 rpm
Front tire Rear tire	13.6 - 24 16.9 - 34

Figure 2: Machine for rainwater harvesting and planting the wheat crop.



1- The blade. 2- The moldboard. 3- The shank. 4- Upper and lower hitch points. 5- Hopper of seeds. 6- Feeding unit. 7- Pressure arm. 8-Feeding tube .9- Point for changing pressure values. 10- Ground wheel to motion feeding unit. 11- Border unit to build ridges. 12- Opener 13-Parts fixed at the back of border to change the shape of ridge surface.

Figure 3: Back and side views of the machine for rainwater harvesting and planting the wheat.

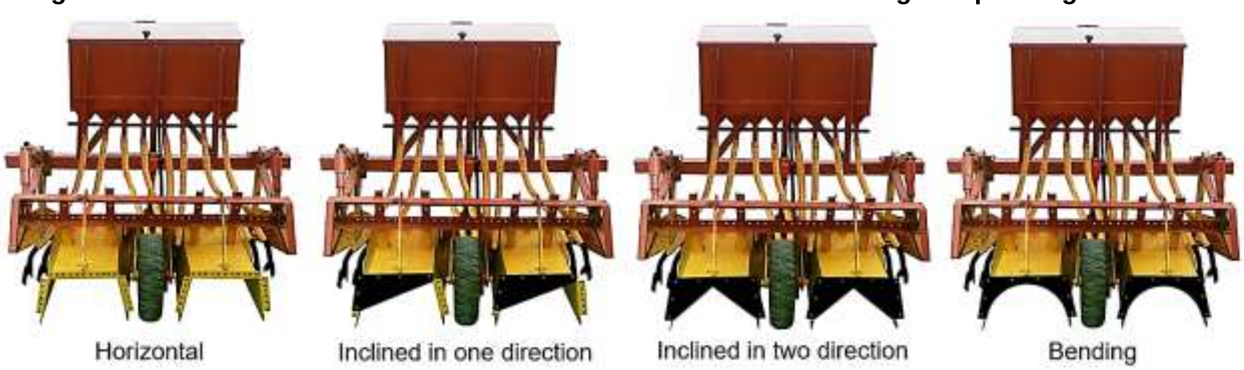


Figure 4: Parts fixed at the back of a border to change the shape of the ridge.

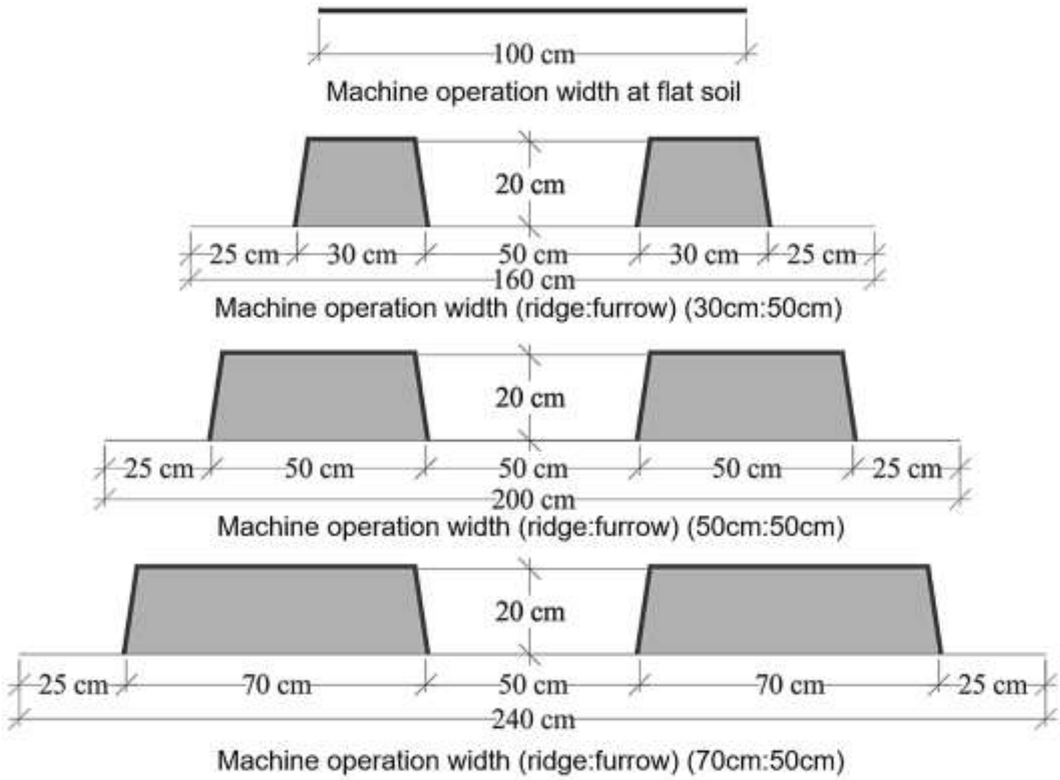


Figure 5: Operation width of machine of the different ridge: furrow ratios.

Experimental design:

Treatments were arranged in a split-split plot design with three replications. The Main plots were the four shapes of ridge surface (horizontal, inclined in one direction, inclined in two directions and bending). The sub-plots were three ridges-furrow ratios (30 cm: 50 cm, 50cm: 50cm and 70 cm: 50 cm). The sub-sub plots were three types of mulching for ridge surface (without cover, asphalt emulsion and plastic film). The diagram for the ridge-furrow system was presented in Figure (6). Sowing on flat soil conducted as control treatment, this treatment was carried out by the same machine where, the digger and border units were canceled to use the machine for planting wheat only in this case the machine width was 100cm and content eight feeding tubes for planting wheat seeds. The previous experiment was carried out during winter season 2016-2017 where the wheat crop was planted. The machine worked at a fixed tractor forward speed of about 4.5 km/h. The whole experimental area was plowed by chisel plow (two passes at about of 20 cm tillage depth and forward speed of about 4.5 km/h) before applying the ridge-furrow system. The slope of the soil surface in the field experiment was about of 2% and the soil surface slope was perpendicular on ridges.

Wheat seeds and planting method:

The wheat seeds was sowed in November, with a rate of 143 kg/ha by seeder unit in the manufactured machine which consisted of eight rows of sowing crop seeds divided into four rows in the middle channel and two rows on each side at one pass of the machine where four rows are completed in each channel after the next pass of the machine. The manufactured machine used for sowing wheat seeds on flat soil at eight the rows where, the digger and border units were raised to disable them and the openers of seeder were collected in a one line for using to sowing on the flat soil.

Measurements:

Pulling force:

Pulling force was measured by hydraulic dynamometer, which, coupled between the two tractors with the attaching machine to estimate its draught force. The average of 10 readings of the draught force was taken at 10 second intervals.

Fuel consumption rate.

Fuel consumption per unit time was determined by measuring the volume of fuel consumed during operation time. It was measured using the fuel meter equipment as shown in Figure (7). The length of line which marked by the marker tool on the paper sheet represents the fuel consumption. The fuel meter was calibrated prior and the volume of fuel was determined accurately.

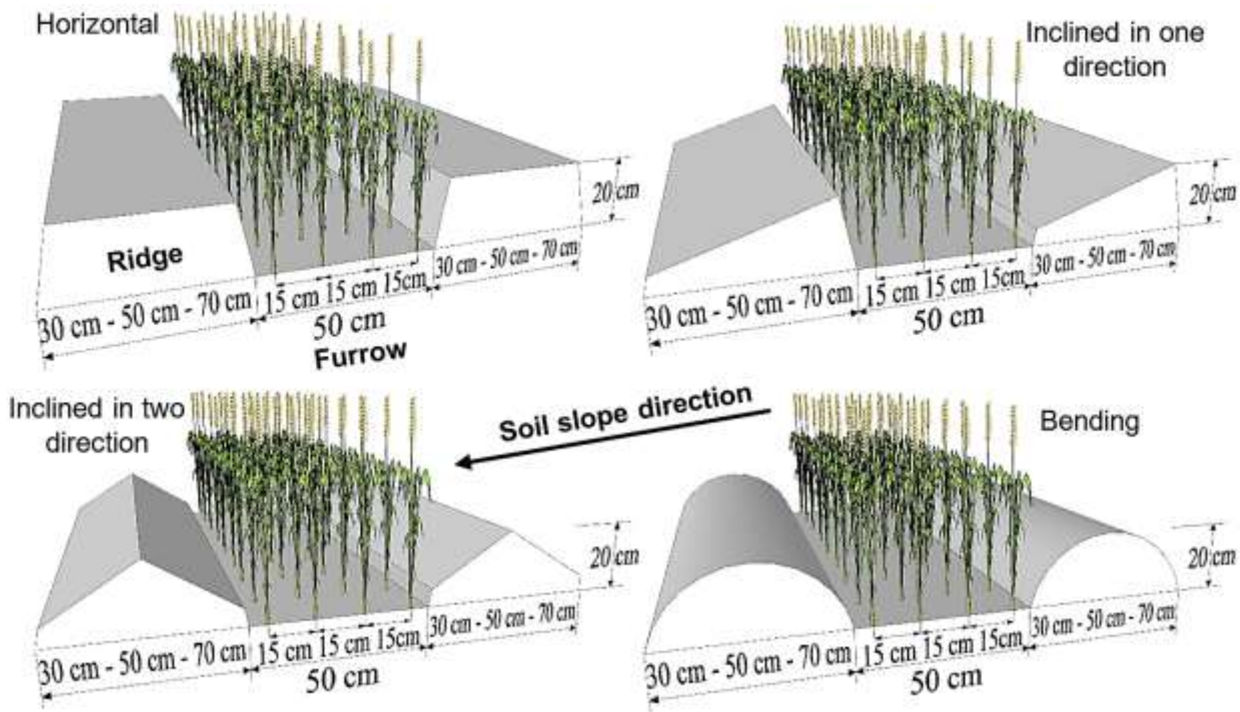


Figure 6 :The diagram for ridge-furrow system.

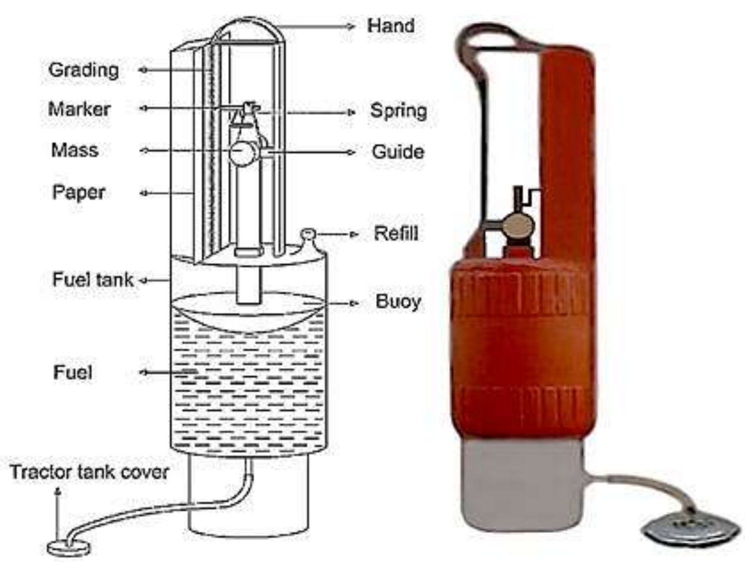


Figure 7: Fuel meter for measuring fuel consumption.

Actual field capacity and field efficiency:

Actual field capacity and field efficiency were calculated by using equations mentioned by **kepner et al. (1978)**.

Soil bulk density:

Soil bulk density was measured using a core method as described by **Black (1986).**

Soil moisture content.

Moisture measurement (TDR 300 soil moisture meter)

Total water stored in the effective root zone.

Water stored in the root zone was determined according to **James (1988)** as follows:

$$TWS = \left(\frac{\theta_{fc} - \theta_{wp}}{100}\right) D_r * \rho_b$$

Where: **TWS** = Water stored in the root zone, (mm/day), Θ_{fc} = Soil moisture content at field capacity, (%), Θ_{wp} = Soil moisture content at permanent wilting point, (%), D_r = Effective root depth, (mm) and ρ_b = Soil bulk density, (g/cm^3).

The total cost of performing a tillage operation:

Total hourly cost was determined according to **EL-Awady (1978)** as follows:

$$\mathbf{C} = \left(\frac{\mathbf{p}}{\mathbf{h}}\right) * \left(\frac{\mathbf{1}}{\mathbf{L}} + \frac{\mathbf{i}}{\mathbf{2}} + \mathbf{t} + \mathbf{r}\right) + (\mathbf{1.2} * \mathbf{RFC} * \mathbf{f}) + \left(\frac{\mathbf{m}}{\mathbf{144}}\right) + \left(\frac{\mathbf{P_1}}{\mathbf{h_1}}\right) * \left(\frac{\mathbf{1}}{\mathbf{L_1}} + \frac{\mathbf{i}}{\mathbf{2}} + \mathbf{t} + \mathbf{r_1}\right)$$

Where: C = Hourly cost, (L.E./h), **P** = Initial price of the tractor, (L.E), **h** = Yearly working hours of tractor. (h/year), **L** = Life expectancy of the tractor, (year), **T** = Annual taxes and overhead ratio, (%), **f** = Fuel price, (L.E./L), **m** = The monthly average wage,(L.E./month), **1.2** = Factor accounting for lubrications, **RFC** = Actual rate of fuel consumption, (L/h), **I** = Annual interest rate,(%), **r** = Annual repairs and maintenance ratio for tractor, (%),P_1 = Initial price of machine, (L.E), h_1 = Yearly working hours of machine, (h/year), r_1 = Annual repairs and maintenance ratio for machine, (%), **144** = Operator monthly average working hours, (h) and L_1: Life expectancy of machine,

Total cost per unit area:

Total cost per unit area was determined as follows:

$$TCA = \frac{C}{AFC}$$

Where: **TCA** = Total cost per unit area, (L.E./ha), **AFC** = Actual field capacity, (ha/h) and **C** = Hourly cost, (L.E./h).

Net profit:

Net profit estimated as follows:

NP = P – TCA

Where: **NP** = Net profit, (L.E./ha), **P** = Profit, (L.E./ha) and **TCA** = Total cost per unit area, (L.E./ha).

Runoff efficiency:

An iron sheet border, 2 mm thickness and 80mm height, was installed around the ridge to collect runoff water from the ridges and to divert the water through two hoses into a bucket as shown in **Figure (8).** Two water-buckets, were placed at the ends of the two water hoses and in holes under the ground. The buckets were emptied after measurement to ensure enough space for the next rainfall. A 1000ml measuring cylinder or calibrated stick was used to measure the amount of runoff. Runoff efficiency was determined as the ratio of runoff volume (collected from the catchment area) to the amount of rainfall in the same area, as follows:

$$ER = \frac{R}{P} X100$$

Where: **ER** = Runoff efficiency, (%), **R** = Volume of collected water runoff after the storm, (liter) and **P** = Total storm precipitation, (mm). Where 1mm precipitation is equivalent to 1-liter water falling on 1m2. The amount of rainfall for each rain event during the winter season 2016-2017 were measured by a rain-gauge device measure amount of rain water falling on the soil in a field. It was manufactured locally and consists of the parts as shown in figure (9) where, the rain gauge calibrated so that each millimeter on the calibrator of the device expresses one millimeter of the amount of rain water falling. The total amount of rainfall was 153mm. The distribution of rainfall during the winter season of 2016-2017 was present in Figure (10) which shows that the highest depths of rainfall were recorded during January and February 2017.

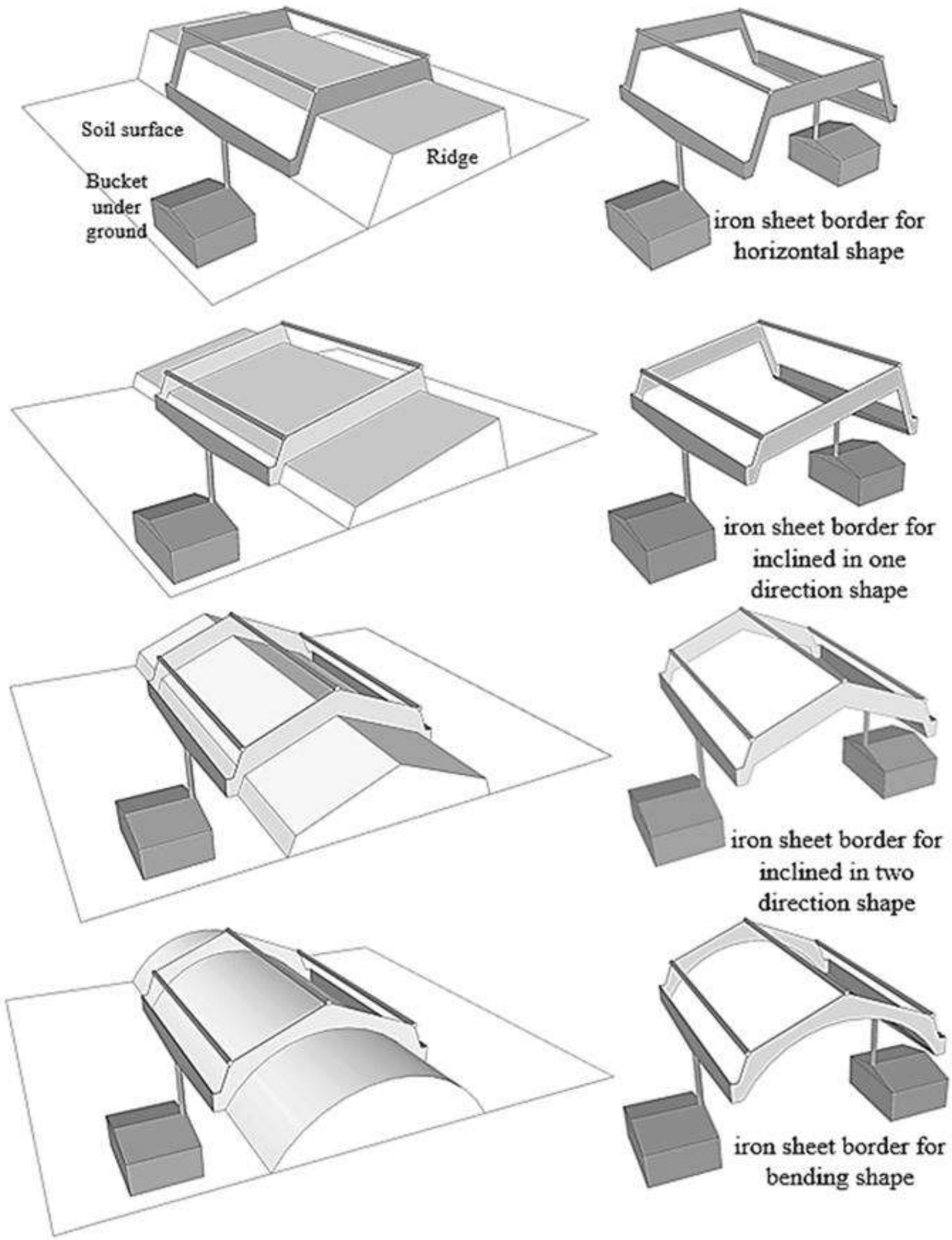


Figure 8: Schematic diagram showing iron sheet border installed around the different shapes of ridge to collect runoff water from the ridges.

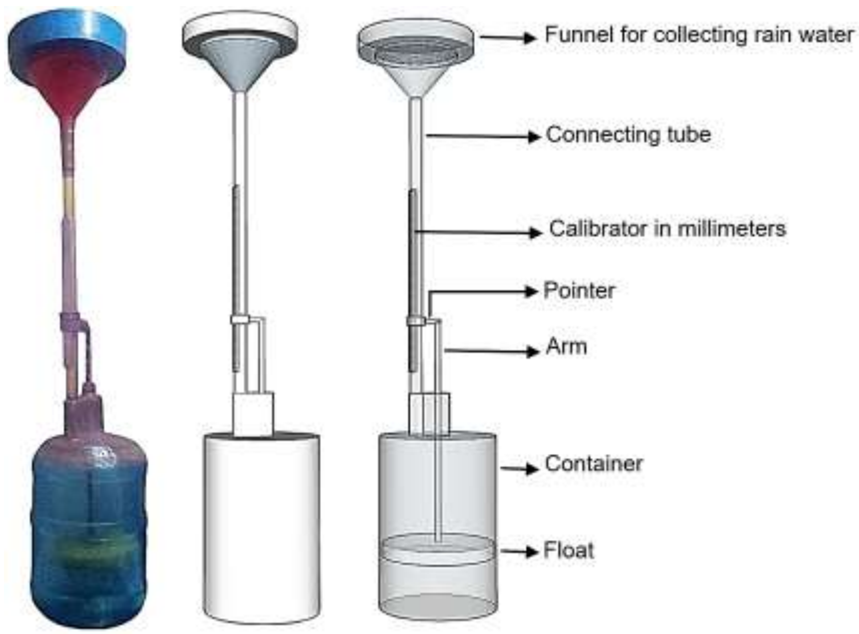


Figure 9: A locally made rain gauge device for measuring rainwater falling in the field.

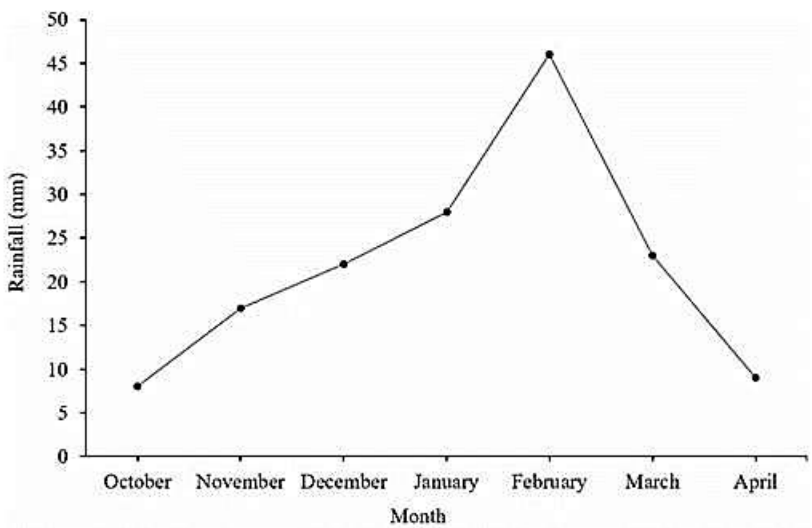


Figure 10: The distribution of rainfall during the winter season of 2016-2017.

RESULT AND DISCUSSION

The performance efficiency of rainwater harvesting machine:

Table (3) showed the machine performance in the field where the results showed significant effect of both of surface shape and width of rainwater harvesting ridges on the machine performance evaluation factors (actual field capacity, field efficiency, pulling force and fuel consumption rate). The average actual field capacity of the machine increased by about 19%

and 29% when increasing the ridge width of 50 cm and 70 cm, respectively, compared to the ridge width 30 cm. This result was because the machine's operating width increased by increasing the ridge width. The average actual field capacity increased by about 2%, 5%, and 8% when the ridge surface shapes chanced to horizontal, inclined in one direction and inclined in two directions, respectively, compared to the bending shape. This result was due to increase soil resistance by changing the ridge shape, which increases the time lost during operation. The results showed that the average actual field capacity of the machine increased by about 52% when carrying out ridge-furrow system for harvesting rainwater compared to the traditional flat soil system._This result was due to increase in the machine operating width when applying the ridge-furrow system compared to the flat soil system. The results also showed an increase in the average field efficiency of the machine by about 8% and 17% with the low ridge width at 50cm and 30cm, respectively, compared with the ridge width 70cm. This result was due to when increasing the ridge width causes increasing the soil resistance to the machine, which increases the time lost during the operation. The average machine field efficiency increased by about 2%, 5%, and 8% when the shape of the ridge surface changed to horizontal, inclined in one direction and inclined in two directions, respectively, compared to the bending ridge shape. The average field efficiency of the machine decreased by about 19% for the ridge-furrow system compared to the traditional flat soil system._On the other hand, the results showed a decreasing in the average pulling force and the fuel consumption rate of the machine by about (15% - 33%) and (19% - 37%) when the ridge widths were 50 cm and 30 cm respectively_compared to 70 cm ridge width. This can be explained by increasing soil resistance when increasing the ridge width. On the same approach, the average pulling force and the fuel consumption rate of the machine decreased by about (2%, 6% and 8%) and (3%, 6% and 8%) when the surface ridge shape changed to horizontal, inclined in one direction and inclined in two directions, respectively, compared to the bending shape. This result was due to the change in the size of the soil formed by changing the ridge shape. The average pulling force and the fuel consumption rate of the machine when applying the traditional flat soil system decreased by about 75% and 81% compared to the ridge-furrow system respectively. This can be explained by the fact that in the application of the ridge-furrow system, three units are used in the machine: digger unit, planting unit and border unit compared to the use one unit only (planting unit) when applying the traditional flat soil system.

Runoff efficiency:

Table (3) showed the effect of the research treatments on the surface runoff efficiency of the rain water where it increased by about 35%, 17% when using plastic and asphalt respectively compared to non-coverage. The average runoff efficiency increased by about 17% and 35% when the ridge width 50 cm and 70 cm respectively compared to the ridge width 30 cm. This result was explained by the fact that when increasing the ridge width, the catchment area of soil increases. The average runoff efficiency increased by about 9%, 14% and 17% when the shapes were inclined in one direction, inclined in two directions and bending respectively compared to the horizontal ridge. This result can be attributed to increase the slope of the ridge surface, increasing the speed of rainwater runoff. The results showed that the average surface runoff efficiency increased by about 105% for the ridge-furrow system compared to the traditional flat soil system.

Soil moisture storage:

Results in Tables (4), (5), (6) and (7) showed the effect of the study treatments on the soil moisture storage. The average soil moisture storage increased by about 22% and 33% when covering the catchment area (ridges) by asphalt and plastic respectively compared to non-coverage treatment. This result because the presence of mulching on the ridges surface increases the runoff efficiency of rain water, which increases the moisture stored in the cultivated areas between ridges.

Table 3: Effect of study treatments on machine performance and runoff efficiency.

Shape of ridge surface	Ridge, Furrrow ratio (cm: cm)	Type of mulching for the ridge	Actual field capacity (ha/h)		Field efficiency (%)		Pulling force (kN)		Fuel consumption (L/h)		Runoff efficiency (%)	
Horizontal	30:50	Without	0.514	g	80	b	10.4	l	8.9	k	57.6	A
		Asphalt									62.1	y
		Plastic									83.1	k
	50:50	Without	0.6	d	75	d	13.7	h	10.8	h	59.4	z
		Asphalt									66.2	w
		Plastic									85.2	i
	70:50	Without	0.66	a	69	f	15.9	e	13.6	e	62.1	y
		Asphalt									70.7	t
		Plastic									87.7	f
Inclined in one direction	30:50	Without	0.5	h	78	c	11.1	k	9.4	j	62.3	y
		Asphalt									74.2	q
		Plastic									86.8	g
	50:50	Without	0.58	e	73	e	14.8	g	12.2	f	64.2	x
		Asphalt									77.3	p
		Plastic									88.3	e
	70:50	Without	0.64	b	67	g	17.2	c	15.3	c	67.8	v
		Asphalt									80.1	n
		Plastic									91.3	c
Inclined in two directions	30:50	Without	0.48	i	76	d	12.7	j	10.5	i	66.1	w
		Asphalt									79.6	o
		Plastic									87.6	f
	50:50	Without	0.56	f	70	f	15.2	f	13.6	e	68.5	u
		Asphalt									81.1	l
		Plastic									91.1	c
	70:50	Without	0.62	c	65	h	18.5	b	16.8	b	71.7	s
		Asphalt									84.4	j
		Plastic									93.5	b
Bending	30:50	Without	0.48	i	75	d	13.4	i	11.2	g	68.3	u
		Asphalt									80.5	m
		Plastic									89.2	d
	50:50	Without	0.55	f	69	f	16.8	d	14.5	d	71.9	s
		Asphalt									83.3	k
		Plastic									91.3	c
	70:50	Without	0.615	c	64	h	19.2	a	17.6	a	73.5	r
		Asphalt									86.2	h
		Plastic									94.7	a
Flat soil			0.37	j	89	a	3.8	m	2.4	l	38.7	B
L.S.D			0.01		1.29		0.1483		0.1657		0.2377	

Table 4: Effect of study treatments on soil moisture storage.

Shape of ridge surface	Ridge, Furrow ratio (cm: cm)	Type of mulching for the ridge	Soil depth (cm)	Bulk density (kg/cm^3)	Gravimetric moisture content (%)		Depth of water (mm) in each soil surface layer		Total depth of water (mm) in the upper soil surface (30cm)		Soil Moisture storage (mm)	
					After rain	Rainless period	After rain	Rainless period	After rain	Rainless period		
Horizontal	30:50	Without	(0 -10)	1.26	8.03	2.26	10.12	2.85	49.80	12.13	37.67	F
			(10-20)	1.34	12.10	2.32	16.21	3.11				
			(20-30)	1.67	14.05	3.69	23.47	6.17				
		Asphalt	(0 -10)	1.24	10.68	2.80	13.24	3.47	62.91	15.32	47.59	B
			(10-20)	1.35	14.95	3.22	20.18	4.35				
			(20-30)	1.66	17.77	4.52	29.49	7.50				
		Plastic	(0 -10)	1.27	12.79	3.40	16.24	4.32	71.58	17.44	54.15	w
			(10-20)	1.36	17.18	4.05	23.36	5.51				
			(20-30)	1.65	19.38	4.61	31.98	7.61				
	50:50	Without	(0 -10)	1.23	9.37	2.52	11.53	3.10	54.97	13.38	41.59	E
			(10-20)	1.32	13.20	3.27	17.42	4.31				
			(20-30)	1.66	15.67	4.46	26.02	7.41				
		Asphalt	(0 -10)	1.24	11.80	3.65	14.63	4.52	69.41	16.90	52.51	y
			(10-20)	1.36	16.28	3.96	22.14	5.39				
			(20-30)	1.65	19.78	4.24	32.64	6.99				
		Plastic	(0 -10)	1.22	14.06	3.93	17.15	4.79	77.35	18.84	58.51	s
			(10-20)	1.32	18.48	4.35	24.39	5.74				
			(20-30)	1.64	21.84	5.07	35.81	8.31				
	70:50	Without	(0 -10)	1.23	10.48	2.75	12.89	3.38	61.59	15.00	46.59	C
			(10-20)	1.32	14.75	3.25	19.47	4.29				
			(20-30)	1.68	17.40	4.36	29.23	7.33				
		Asphalt	(0 -10)	1.21	13.96	3.77	16.89	4.56	76.87	18.72	58.15	t
			(10-20)	1.34	17.72	4.19	23.74	5.61				
			(20-30)	1.63	22.23	5.25	36.24	8.55				
		Plastic	(0 -10)	1.24	14.73	3.92	18.27	4.86	83.97	20.45	63.52	m
			(10-20)	1.35	19.40	4.97	26.19	6.71				
			(20-30)	1.63	24.24	5.45	39.51	8.88				
Flat soil			(0 -10)	1.11	7.24	1.93	8.04	2.14	41.37	10.07	31.3	G
			(10-20)	1.19	10.16	2.48	12.09	2.95				
			(20-30)	1.64	12.95	3.04	21.24	4.98				
L.S.D			–								0.3328	

Table 5: Effect of study treatments on soil moisture storage.

Shape of ridge surface	Ridge, Furrow ratio (cm:cm)	Type of mulching for ridge	Soil depth (cm)	Bulk density (kg/cm^3)	Gravimetric moisture content (%)		Depth of water (mm) in each soil surface layer		Total depth of water (mm) in the upper soil surface (30cm)		Soil moisture storage (mm)	
					After rain	Rainless period	After rain	Rainless period	After rain	Rainless period		
Inclined in one direction	30:50	Without	(0 -10)	1.25	8.60	2.51	10.75	3.14	58.46	14.23	44.23	D
			(10-20)	1.37	12.10	3.17	16.58	4.34				
			(20-30)	1.66	18.75	4.07	31.13	6.75				
		Asphalt	(0 -10)	1.22	12.52	2.91	15.27	3.55	71.21	17.34	53.87	w
			(10-20)	1.34	16.24	4.08	21.76	5.47				
			(20-30)	1.65	20.72	5.04	34.18	8.32				
		Plastic	(0 -10)	1.21	14.32	3.48	17.33	4.21	79.76	19.43	60.33	q
			(10-20)	1.32	18.64	4.88	24.61	6.44				
			(20-30)	1.64	23.06	5.35	37.82	8.78				
	50:50	Without	(0 -10)	1.21	10.83	2.90	13.11	3.51	64.60	15.73	48.87	A
			(10-20)	1.34	15.08	3.22	20.21	4.32				
			(20-30)	1.63	19.18	4.85	31.26	7.90				
		Asphalt	(0 -10)	1.24	13.80	3.44	17.11	4.27	78.91	19.21	59.70	r
			(10-20)	1.35	17.96	4.61	24.25	6.23				
			(20-30)	1.62	23.18	5.38	37.55	8.71				
		Plastic	(0 -10)	1.25	14.79	3.82	18.49	4.77	87.70	21.36	66.34	k
			(10-20)	1.36	19.74	4.93	26.84	6.70				
			(20-30)	1.67	25.37	5.92	42.37	9.89				
	70:50	Without	(0 -10)	1.20	12.58	2.84	15.10	3.41	70.25	17.11	53.14	x
			(10-20)	1.34	15.85	3.97	21.24	5.32				
			(20-30)	1.64	20.68	5.11	33.91	8.38				
		Asphalt	(0 -10)	1.22	15.15	4.07	18.48	4.97	85.77	20.89	64.88	l
			(10-20)	1.35	19.57	5.08	26.42	6.86				
			(20-30)	1.67	24.47	5.43	40.87	9.06				
		Plastic	(0 -10)	1.21	15.50	4.39	18.75	5.31	94.79	23.08	71.71	e
			(10-20)	1.34	21.10	5.35	28.28	7.17				
			(20-30)	1.68	28.43	6.31	47.76	10.60				
Flat soil			(0 -10)	1.11	7.24	1.93	8.04	2.14	41.37	10.07	31.3	G
			(10-20)	1.19	10.16	2.48	12.09	2.95				
			(20-30)	1.64	12.95	3.04	21.24	4.98				
L.S.D			–								0.3328	

Table 6: Effect of study treatments on soil moisture storage.

Shape of ridge surface	Ridge, Furrow ratio (cm:cm)	Type of mulching for ridge	Soil depth (cm)	Bulk density (kg/cm^3)	Gravimetric moisture content (%)		Depth of water (mm) in each soil surface layer		Total depth of water (mm) in the upper soil surface (30cm)		Soil moisture storage (mm)	
					After rain	Rainless period	After rain	Rainless period	After rain	Rainless period		
Inclined in two directions	30:50	Without	(0 -10)	1.24	11.87	2.68	14.72	3.32	66.88	16.28	50.60	z
			(10-20)	1.33	15.22	3.92	20.24	5.21				
			(20-30)	1.64	19.46	4.73	31.92	7.75				
		Asphalt	(0 -10)	1.23	14.37	3.57	17.68	4.39	81.08	19.75	61.33	o
			(10-20)	1.32	18.82	4.86	24.84	6.42				
			(20-30)	1.63	23.66	5.48	38.56	8.94				
		Plastic	(0 -10)	1.20	15.78	4.08	18.94	4.89	89.50	21.80	67.70	i
			(10-20)	1.36	20.05	5.10	27.27	6.93				
			(20-30)	1.66	26.08	6.01	43.29	9.98				
	50:50	Without	(0 -10)	1.22	12.65	3.02	15.43	3.69	73.62	17.93	55.69	v
			(10-20)	1.32	16.42	4.17	21.67	5.50				
			(20-30)	1.64	22.27	5.33	36.52	8.74				
		Asphalt	(0 -10)	1.25	14.94	3.93	18.67	4.91	88.42	21.54	66.89	j
			(10-20)	1.35	20.08	4.95	27.11	6.68				
			(20-30)	1.67	25.53	5.96	42.64	9.95				
		Plastic	(0 -10)	1.26	15.27	4.51	19.24	5.68	97.32	23.70	73.62	d
			(10-20)	1.34	22.37	5.63	29.97	7.54				
			(20-30)	1.68	28.64	6.24	48.11	10.48				
	70:50	Without	(0 -10)	1.22	14.32	3.48	17.47	4.24	80.36	19.57	60.79	p
			(10-20)	1.35	18.24	4.65	24.62	6.28				
			(20-30)	1.64	23.34	5.52	38.27	9.05				
		Asphalt	(0 -10)	1.25	15.01	4.10	18.76	5.13	94.19	22.94	71.25	f
			(10-20)	1.36	20.93	5.32	28.47	7.24				
			(20-30)	1.67	28.12	6.33	46.96	10.57				
		Plastic	(0 -10)	1.23	16.54	4.97	20.34	6.11	104.30	25.40	78.90	b
			(10-20)	1.32	23.67	5.95	31.25	7.85				
			(20-30)	1.64	32.14	6.98	52.71	11.44				
Flat soil			(0 -10)	1.11	7.24	1.93	8.04	2.14	41.37	10.07	31.3	G
			(10-20)	1.19	10.16	2.48	12.09	2.95				
			(20-30)	1.64	12.95	3.04	21.24	4.98				
L.S.D			–								0.3328	

Table 7: Effect of study treatments on soil moisture storage.

Shape of ridge surface	Ridge, Furrow ratio (cm:cm)	Type of mulching for ridge	Soil depth (cm)	Bulk density (kg/cm^3)	Gravimetric moisture content (%)		Depth of water (mm) in each soil surface layer		Total depth of water (mm) in the upper soil surface (30cm)		Soil moisture storage (mm)	
					After rain	Rainless period	After rain	Rainless period	After rain	Rainless period		
Bending	30:50	Without	(0 -10)	1.21	12.36	2.98	14.95	3.61	69.65	16.96	52.69	y
			(10-20)	1.35	15.24	3.87	20.57	5.23				
			(20-30)	1.63	20.94	4.98	34.13	8.12				
		Asphalt	(0 -10)	1.19	15.28	3.87	18.18	4.61	82.76	20.15	62.61	n
			(10-20)	1.31	19.96	4.98	26.15	6.53				
			(20-30)	1.64	23.43	5.49	38.43	9.01				
		Plastic	(0 -10)	1.20	15.34	4.08	18.41	4.89	92.15	22.44	69.71	g
			(10-20)	1.30	21.63	5.46	28.12	7.10				
			(20-30)	1.65	27.65	6.33	45.62	10.45				
	50:50	Without	(0 -10)	1.22	13.64	3.61	16.64	4.40	76.27	18.58	57.69	u
			(10-20)	1.34	17.55	4.07	23.52	5.45				
			(20-30)	1.67	21.62	5.23	36.11	8.73				
		Asphalt	(0 -10)	1.19	15.46	4.06	18.40	4.83	90.34	22.00	68.34	h
			(10-20)	1.30	21.62	5.32	28.10	6.91				
			(20-30)	1.64	26.73	6.26	43.84	10.26				
		Plastic	(0 -10)	1.25	15.80	4.74	19.75	5.92	99.61	24.26	75.35	c
			(10-20)	1.34	22.70	5.87	30.42	7.86				
			(20-30)	1.67	29.60	6.28	49.44	10.48				
	70:50	Without	(0 -10)	1.23	15.02	3.93	18.48	4.83	83.97	20.45	63.52	m
			(10-20)	1.33	19.99	4.97	26.59	6.61				
			(20-30)	1.66	23.43	5.43	38.90	9.01				
		Asphalt	(0 -10)	1.24	15.64	4.65	19.39	5.77	97.68	23.79	73.89	d
			(10-20)	1.35	22.30	5.69	30.10	7.68				
			(20-30)	1.63	29.56	6.34	48.19	10.34				
		Plastic	(0 -10)	1.25	16.58	4.96	20.73	6.20	105.98	25.81	80.17	a
			(10-20)	1.37	23.09	5.88	31.64	8.05				
			(20-30)	1.64	32.69	7.05	53.61	11.56				
Flat soil			(0 -10)	1.11	7.24	1.93	8.04	2.14	41.37	10.07	31.3	G
			(10-20)	1.19	10.16	2.48	12.09	2.95				
			(20-30)	1.64	12.95	3.04	21.24	4.98				
L.S.D			–								0.3328	

Wheat yield:

The results obtained in Table (8) showed significant differences between the wheat yield values (grain and straw). The average yield of the grains increased by about 32% - 52% and straw 33% - 51% when using the asphalt emulsion and plastic as mulching respectively compared to the non-coverage. This result because when covering the ridges surface increases the runoff efficiency of rain water which increasing the amount of water collected in the cultivated areas between ridges. On the same face, the average wheat yield increased by about 7% - 11% for grain and 6% - 10% for straw when decreased the ridges width to 50cm and 30cm, respectively, compared to ridge width 70cm. This result explained by the fact that, although the increasing in ridge width causes increased the amount of water collected in the cultivated area and increased wheat productivity, but this increasing in productivity does not compensate the decreasing in productivity due to the decreasing in cultivated area, (Where rainwater harvesting areas are larger than cultivated area), which causing reduced productivity by increasing the ridge width. The results indicated that the average wheat yield increased by about 13%, 25% and 30% for grain and 12%, 24% and 29% for straws at shapes inclined in one direction, inclined in two directions and bending, respectively, compared to the horizontal shape. This result because increasing the slope of the ridge surface increases the amount of water collected in cultivated area between ridges. The results also showed that the average yield of wheat increased by about 84% and 85% for grain and straw respectively, when using the ridge-furrow system compared to the traditional flat soil system.

Economic assessment:

Table (8) showed the net profit was realized from the application of this study for the cultivation of wheat crop under rainfed conditions by using the ridge-furrow system where the results indicated an increase in average net profit by about 4% and 9% when using asphalt emulsion and plastic respectively as mulching for ridges compared to non-coverage. This result can be attributed to the fact that although the cost of using the plastic cover has increased compared other types of coverage, it has achieved the highest wheat yield, which achieved higher profits compared to costs. The results also showed an increase in the average net profit by about 9% and 14% of ridge width 50 cm and 30 cm, respectively, compared to the ridge width 70 cm. The reason for this result was that wheat productivity increased when ridge width decreased, which caused increasing of net profit. The average net profit increased by about 17%, 33% and 39% at the shapes inclined in one direction, inclined in two directions and bending, respectively, compared to the horizontal shape. The results showed that an average net profit increase by about 58% when using the ridge-furrow system compared to the traditional flat soil system.

Estimating optimum ridge width:

Regression equations were calculated for the relationship between the yield as a dependent variable and the ridge width (rainwater harvesting areas) as an independent variable as shown in Figure (10). These equations were differentiated to obtain the optimum ridge width, which achieves the highest wheat grain yield. The results in Table (9) indicated that the highest wheat grain yield under conditions of non-mulching were achieved when the ridge width by about 38 cm, 42 cm, 44 cm and 45 cm at the ridge shapes of horizontal, inclined in one direction, inclined in two directions and bending, respectively. Under the mulching conditions of asphalt emulsion, the highest wheat grain yield was achieved when the ridge width by about 45 cm, 46 cm, 47 cm and 47 cm at the ridge shapes of horizontal, inclined in one direction, inclined in two directions and bending, respectively. But under the mulching conditions of plastic, the highest wheat grain yield was achieved when the ridge width by about 46 cm, 47 cm, 48 cm and 48 cm at the ridge shapes of horizontal, inclined in one direction, inclined in two directions and bending, respectively.

Table 8: Effect of study treatments on wheat yield and economic assessment.

Shape of ridge surface	Ridge, Furrrow ratio (cm: cm)	Type of mulching for the ridge	Wheat grain yield (kg/ha)		Wheat straw yield (kg/ha)		Profit (L.E/ha)		Total cost (L.E/ha)		Net profit (L.E/ha)	
Horizontal	30:50	Without	1848	t	2667	op	10590	B	707	qrs	9883	v
		Asphalt	2498	m	3621	ij	14336	s	4040	jk	10295	t
		Plastic	2964	h	4267	efg	16976	k	5945	cd	11031	q
	50:50	Without	1717	u	2502	p	9869	c	621	u	9248	x
		Asphalt	2405	n	3512	jk	13833	u	3955	mn	9879	v
		Plastic	2817	j	4090	fgh	16176	n	5860	fg	10317	t
	70:50	Without	1581	v	2293	q	9076	D	590	u	8486	z
		Asphalt	2221	q	3219	lm	12748	x	3924	n	8824	y
		Plastic	2671	l	3848	hi	15302	q	5829	g	9474	w
Inclined in one direction	30:50	Without	2126	r	3079	mn	12200	y	731	qr	11469	p
		Asphalt	2812	j	4048	fgh	16105	o	4064	ij	12040	m
		Plastic	3219	e	4650	cd	18457	f	5969	bc	12488	k
	50:50	Without	2002	s	2914	no	11507	z	657	st	10850	r
		Asphalt	2726	k	3952	gh	15648	p	3990	lm	11657	o
		Plastic	3121	f	4474	de	17855	h	5895	ef	11960	n
	70:50	Without	1850	t	2702	op	10643	A	629	tu	10014	u
		Asphalt	2524	m	3660	ij	14486	r	3962	mn	10524	s
		Plastic	2931	i	4190	efg	16752	l	5867	fg	10886	r
Inclined in two directions	30:50	Without	2433	n	3531	jk	13971	t	764	pq	13207	g
		Asphalt	3074	g	4457	de	17643	i	4098	hi	13545	f
		Plastic	3507	b	5005	ab	20033	c	6002	ab	14031	d
	50:50	Without	2329	o	3360	jkl	13345	v	698	rs	12648	j
		Asphalt	2988	h	4336	def	17155	j	4031	jkl	13124	hi
		Plastic	3405	c	4883	bc	19479	d	5936	cde	13543	f
	70:50	Without	2119	r	3083	mn	12176	y	662	tu	11514	p
		Asphalt	2807	j	4043	fgh	16081	o	3995	lm	12086	m
		Plastic	3212	e	4614	cd	18386	g	5900	ef	12486	k
Bending	30:50	Without	2526	m	3669	it	14507	r	781	p	13726	e
		Asphalt	3202	e	4643	cd	18381	g	4114	h	14267	b
		Plastic	3636	a	5198	a	20781	a	6019	a	14762	a
	50:50	Without	2410	n	3481	jkl	13814	u	719	qr	13095	i
		Asphalt	3081	g	4410	de	17614	i	4052	jk	13562	f
		Plastic	3526	b	5026	ab	20136	b	5957	cd	14179	c
	70:50	Without	2271	p	3310	klm	13057	w	679	st	12379	l
		Asphalt	2905	i	4183	efg	16638	m	4012	kl	12626	t
		Plastic	3336	d	4786	bc	19086	e	5917	de	13169	gh
Flat soil			1460	w	2093	r	8350	E	845	o	7505	A
L.S.D			28.212		206.31		42.445		33.95		54.1	

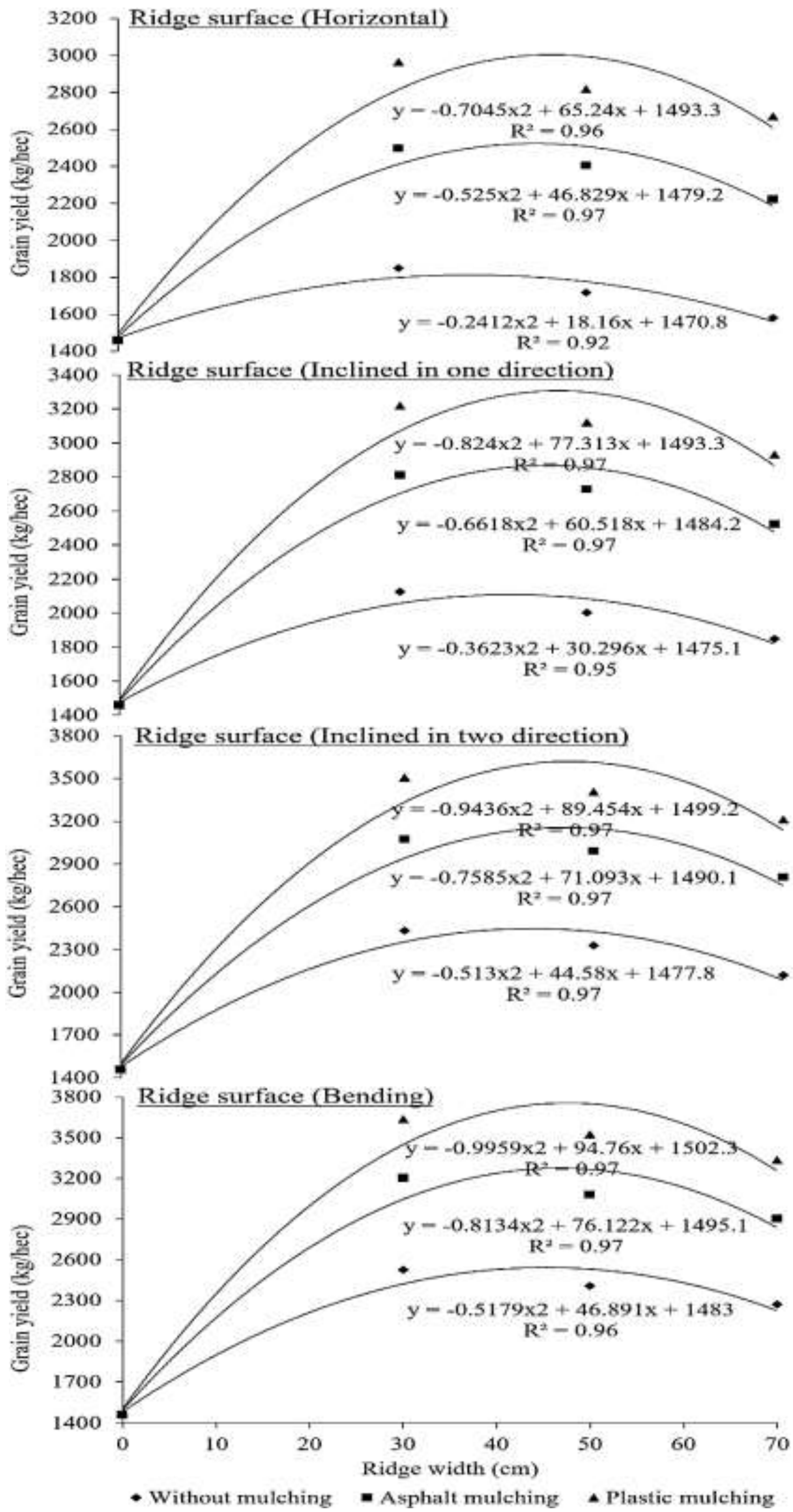


Figure 10: Regression equations for the relationship between ridge width and wheat grain yield.

Table 9: Optimum ridge width.

Shape of ridge surface	Without mulching				Asphalt mulching				Plastic mulching			
	Ridge width (cm)	Grain yield (kg/ha)	Optimum ridge width (cm)	Maximum grain yield (kg/ha)	Ridge width (cm)	Grain yield (kg/ha)	Optimum ridge width (cm)	Maximum grain yield (kg/ha)	Ridge width (cm)	Grain yield (kg/ha)	Optimum ridge width (cm)	Maximum grain yield (kg/ha)
Horizontal	30	1848	38	1860	30	2498	45	2524	30	2964	46	3010
	50	1717			50	2405			50	2817		
	70	1581			70	2221			70	2671		
Inclined in one direction	30	2126	42	2131	30	2812	46	2869	30	3219	47	3307
	50	2002			50	2726			50	3121		
	70	1850			70	2524			70	2931		
Inclined in two directions	30	2433	44	2448	30	3074	47	3157	30	3507	48	3619
	50	2329			50	2988			50	3405		
	70	2119			70	2807			70	3212		
Bending	30	2526	45	2545	30	3202	47	3276	30	3636	48	3757
	50	2410			50	3081			50	3526		
	70	2271			70	2905			70	3336		

CONCLUSIONS

Based on the previous results discussion of the research, it was clarified that the prototype machine succeeded in applying the ridge-furrow system of cultivation the wheat crop under rainwater harvesting conditions. The results showed that the best treatment under the ridge-furrow system achieved the highest wheat grain yield 3636 kg/ha and the highest profit 14762 L.E/ha was in the bending ridge shape, plastic coverage and ridge width 30 cm. The optimum ridge width (as a catchment area) about of 48cm was determined by differential of regression equations for the relationship between wheat grain yield and ridge width, which achieved the highest wheat grain yield, with plastic surface covered and bending ridge shape. Application of the ridge-furrow system achieved the highest wheat grain yield and the highest profit about of 84% and 57%, respectively, compared to the traditional flat soil system, which applied in the study area.

REFERENCES

Abbas, G., A. Hussain, A. Ahmad and S. A. Wajid (2005). Water use efficiency of maize as affected by irrigation schedules and nitrogen rates. J. Agric. Soc. Sci. 1, 339-342.

Black, G. R., (1986). Bulk density. P. 374-390. In Page, et. El. (eds.). Methods of Soil Analysis, Part 1. Physical and Mineralogical Methods, Am. Soc. Agron. Inc. Medison. Wis. USA.

Boers, T. M. (1994). Rainwater harvesting in arid and semi-arid zones. International institute for land reclamation and improvement. Wageningen. The Netherlands.

Carter, D. C and S. Miller (1991). Three years' experience with an on-farm macro-catchment water harvesting system in Botswana. Agricultural Water Management, 19(3): 191-203.

Deng, X. P., L. Shan, H. P. Zhang and C. Turner Neil (2006). Improving agricultural water use efficiency in arid and semiarid areas of China. Agric. Water Manage. 80, 23-40.

El-Awady, M. N. (1978). Engineering of Tractor and Agricultural Machinery. Text Book, (in Arabic), Fac. of Agric. Ain Shams Univ., Cairo, Egypt.

Frasier, G.W. (1980). Harvesting water for agricultural, wildlife, and domestic uses. J. Soil Water Cons. 35, 125-128.

Frasier, G.W. (1994). Water Harvesting/Runoff Farming Systems for Agricultural Production. In: FAO, Water Harvesting for Improved Agricultural Production. Expert Consultation, Cairo, Egypt 21–25 Nov. 1993, FAO, Rome, pp. 57–73.

Gan, Y. T., K. H. M. Siddique, N. C. Turner, X. G. Li, J. Y. Niu, C. Yang, L. Liu and Q. Chai (2013). Ridge-Furrow Mulching Systems an innovative technique for boosting crop productivity in semiarid rain-fed environments. Adv. Agron 117,429-476.

Gu, X, Y. Li and Y. Du (2016). Continuous ridges with film mulching improve soil water content, root growth, seed yield and water use efficiency of winter oilseed rape. Ind Crop Prod 85:139-148.

Hu, X. Y., S. H. Tao and L. X. Wang (1997). Research on ridge and furrow planting of proso in semiarid and drought inclined area. Agric Res in the Arid Areas 15(1):44-49 (in Chinese in English abstract).

James, L. G. (1988). Principles of farm irrigation system design. John Willey & Sons (ed.), New York, pp. 543.

Jia, Y., F. M Li, X. L. Wang and S. M. Yang (2006). Soil water and alfalfa yields as affected by alternating ridges and furrows in rainfall harvest in a semiarid environment. Field Crops Res. 97, 167-175.

Jin, Y. H., D. W. Zhou and S. C. Jiang (2010). Comparison of soil water content and corn yield in furrow and conventional ridge sown systems in a semiarid region of China. Agric. Water Manage. 97: 326-332.

Kepner, R. A., R. Bainer and E. L. Barger (1978). Principles of Farm Machinery. Ch 5, the AVI Publishing Company.

Klute, A. (1986). Laboratory measurement of hydraulic conductivity of saturated soil. p. 210-220. In Page, et. El. (eds.). Methods of Soil Analysis, Part I. Physical and Mineralogical Methods, Am. Soc. Agron. Inc. Medison. Wis. USA.

Li, C., C. Wang, X. Wen, X. Qin, Y. Liu, J. Han, Y. Li, Y. Liao and W. Wu (2017). Ridge-furrow with plastic film mulching practice improves maize productivity and resource use efficiency under the wheat-maize double-cropping system in dry semi-humid areas. Field Crops Res 203: 201-211.

Li, C., X. Wen, X. Wan, Y. Liu, J. Han, Y. Liao and W. Wu (2016). Towards the highly effective use of precipitation by ridge-furrow with plastic film mulching instead of relying on irrigation resources in a dry semi humid area. Field Crops Res 188:62-73

Li, F. M., A. H. Guo and H. Wei (1999). Effects of clear plastic film mulch on yield of spring wheat. Field Crops Res. 63: 79-86.

Li, R., R.M. Cui, Z.K. Jia, Q.F. Han, W.T. Lu, X.Q. Hou (2011). Effects of different furrow-ridge mulching ways on soil moisture and water use efficiency of winter wheat. Scientia Agric. Sinica 44, 3312–3322.

Li, W.W., Q.L. Zhuang, W. Wu, X.X. Wen, J. Han, Y.C. Liao, (2019). Effects of plastic film mulching ridge–furrow planting on soil CO2 efflux in a maize field in the Chinese Loess Plateau. Agr. Forest Meteorol. 264, 200–212.

Li, X. L., D. R. Su and Q. H. Yuan (2007). Ridge-furrow planting of alfalfa (Medicago sativa L.) for improved rainwater harvest in rainfed semiarid areas in Northwest China. Soil Till. Res. 93: 117-125.

Li, X. Y. (2000). Experimental study on rainfall harvesting and micro-catchment model for ecosystem construction in the transitional zone between arid and semiarid region. PhD. Thesis, Cold and Arid Regions Environmental and Engineering Research Institute, Chinese Academy of Sciences (in Chinese with English summary).

Li, X. Y. and J. D. Gong (2002). Effects of different ridge/furrow ratios and supplemental irrigation on crop production in ridge and furrow rainfall harvesting system with mulches. Agri. Water Manage. 54, 243-254.

Li, X. Y. and R. L. Zhang (2005). On-field ridge and furrow rainwater harvesting and mulching combination for corn production in dry areas of Northwest China. J. Soil Water Conserve. 19: 45-48, 52.

Li, X. Y., J. D. Gong and X. H. Wei (2000). In-situ rainwater harvesting and gravel mulch combination for corn production in the dry semiarid region of China. J. Arid Environ. 46, 371-382.

Li, X. Y., J. D. Gong, Q. Z. Gao and F. R. Li (2001). Incorporation of ridge and furrow method of rainfall harvesting with mulching for crop production under semiarid conditions. Agric. Water Manage. 50: 173-183.

Li, X. Y., W. W. Zhao, Y. X. Song, W. Wang and X. Y. Zhang (2008). Rainfall harvesting on slopes using contour furrows with plastic-covered transverse ridges for growing Caragana korshinskii in the semiarid region of China. Agr Water Manage 95:539–544.

Li, X., P. Shi, Y. Sun, J. Tang and Z. Yang (2006). Influence of various in situ rainwater harvesting methods on soil moisture and growth of Tamarix ramosissima in the semiarid Loess region of China. Forest Ecol Manag 233:143-148.

Lv, Y., R.H. Wang, Z.Y. Cai (2009). Climatic change and influence in arid and semi-arid area of China. J. Arid Land Resour. Environ. 23, 65–71.

Mudatenguha, F., J. Anena, C. K. Kiptum (2014). In situ rain water harvesting techniques increase maize growth and grain yield in a semi-arid agroecology of nyagatare, Rwanda. International Journal of Agriculture & Biology, 16(5): 996-1000.

Oweis, T., A. Hachum, (2006). Water harvesting and supplemental irrigation for improved water productivity of dry farming systems in West Asia and North Africa. Agric. Water Manage. 80, 57–73.

Patrick, G., G. Chales, M. Joseph and M. Edword (2004). Effects of soil management practices and tillage system on surface soil water conservation and crust formation on a sandy loam in semi-arid Kenya. Soil Till. Res. 75, 99-186.

Prinz, D., S. Wolfer, (1999). Traditional techniques of water management to cover future irrigation water demand. Z. f. Bewässerungswirtschaft 34 (1), 41–60 ISSN 0049-8602.

Qin, S. H., J. L. Zhang, H. L. Dai, D. Wang and D. M. Li (2014). Effect of ridge–furrow and plastic-mulching planting patterns on yield formation and water movement of potato in a semi-arid area. Agric. Water Manage. 131, 87-94.

Qin, S.H., L.L. Li (2005). Accumulation and distribution of dry matter and grain filling of spring wheat post anthesis under supplementary irrigation catchments rainfall. Journal of Soil and Water Conservation 19, 173–177.

Qin, S.H., L.L. Li, D. Wang, J.L. Zhang, Y.L. Pu (2013). Effects of limited supple-mental irrigation with catchment rainfall on rain-fed potato in semi-arid a reason the Western Loess Plateau, China. American Journal of Potato Research 90, 33–42.

Reiz, C., P. Maulder, and L. Begemann (1988). Water harvesting for plant production. World Bank Technical Paper 91. Washington, DC, USA.

Ren, X. L, Z. K Jia and X. L Chen (2008). Rainfall concentration for increasing corn production under semiarid climate. Agric Water Manage 95:1293-1302.

Ren, X., X. Chen, T. Cai, T. Wei, Y. Wu, S. Ali, P. Zhang, Z. Jia (2017). Effects of ridge–furrow system combined with different degradable mulching materials on soil water conservation and crop production in semi–humid areas of China. Front. Plant Sci. 8.

Salem, H.M., C. Valero, M.A. Muñoz, M.G. Rodríguez (2015). Effect of integrated reservoir tillage for in-situ rainwater harvesting and other tillage practices on soil physical properties. Soil and Tillage Research 151, 50-60.

Shan, L., M. Xu, (1991). Water-saving agriculture and its physio-ecological bases. Chinese Journal of Applied Ecology 2, 70–76.

Tian, Y., D. Su, F. Li, X. Li (2003). Effect of rainwater harvesting with ridge and furrow on yield of potato in semiarid areas. Field Crops Res. 84, 385–391.

Wang, Q., E. H. Zhang, F. M. Li, and F. R. Li (2008). Runoff efficiency and the technique of micro-water harvesting with ridges and furrows, for potato production in semi-arid areas. Water Resource. Manage. 22:1431-1443.

Wang, Q., X. Song, F. Li, G. Hu, Q. Liu, E. Zhang, H. Wang and R. Davies (2015b). Optimum ridge-furrow ratio and suitable ridge-mulching material for alfalfa production in rainwater harvesting in semi-arid regions of China. Field Crops Res 180:186-196.

Wang, Q., X. Y. Song, F. C. Li, G. G. Hu, Q. L. Liu and E. H. Zhang (2015a). Optimum ridge-furrow ratio and suitable ridge-mulching material for alfalfa production in rainwater harvesting in semi-arid regions of China. Field Crops Res. 180, 186-196.

Wang, X., F. Li, Y. Jia and W. Shi (2005). Increasing potato yields with additional water and increased soil temperature. Agr Water Manage 78: 181-194.

Wu, Y., Z. K. Jia and X. L. Ren (2015). Effects of ridge and furrow rainwater harvesting system combined with irrigation on improving water use efficiency of maize (Zea mays L.) in semi-humid area of China. Agricultural Water Management, 158: 1-9.

Xiao, Y. L., J. Dong, Q. Z. Gao and F. R. Li (2001). Incorporation of ridge and furrow method of rainfall harvesting with mulching for crop production under semiarid conditions. Agric. Water Management 50 (3) 173-183.

Zhou, L. M., F. M. Li, S. L. Jin and Y. J. Song (2009). How two ridges and the furrow mulched with plastic film affect soil water, soil temperature and yield of maize on the semiarid Loess Plateau of China. Field Crops Res.113: 41-47.

Zhou, L. M., F. Zhang and C. A. Liu (2015). Improved yield by harvesting water with ridges and sub grooves using buried and surface plastic mulch in a semiarid area of China. Soil Tillage Res. 150, 21-29.