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Development of one row installation machine for subsurface drip irrigation lines and its effects on tomato production

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ABSTRACT

This study was conducted to develop a manual steering one row locally fabricated drip lines installation machine, and evaluate its performance rate, efficiency and operating costs compared with manual installing. Also, the effect of deficit irrigation regime (DIR) under burial depth on tomato plant growth performance "plant height, root length, total dry biomass, and total marketable yield"; water use efficiency "WUE & TYWUE"; yield response factor "Ky" and yield depression were investigated. Treatments consisted of three levels of DIR (85; 70 and 55 % ETc) represented by (RI); (RII) and (RIII) respectively, throughout the whole growing season, and three burial depths of subsurface drip T-tape at (5; 15 and 25 cm) represented by (DI); (DII) and (DIII) respectively; compared with the common tomato growing practice by using GR-drip tuber 16 mm installed at the soil surface (D0) with 100 % ETc (R0). The applied treatments were: T1 "control" (R0&D0); T2 (RI&D1); T3 (RI&DII); T4 (RI&DIII); T5 (RII & D1); T6 (RII&DII); T7 (RII&DIII); T8 (RIII&D1); T9 (RIII &DII) and T10 (RIII &DIII). The results showed that, the highest value of depth uniformity index by using the proposed machine and manual method were 10.54 and 2.9 respectively, recorded at burial depth 25 cm. The power consumption of the proposed machine ranged between 2.303 and 1.885 Kw/h recorded during installing the drip lines at the burial depth 25 cm and at the soil surface respectively. As far the tomato plant growth performance, the highest value of plant height, total dry biomass and total marketable yield were (68.83 cm); (3.84 Mg/fed) and (32.88 Mg/fed) respectively recorded with treatment T1(100% ETc & at the soil surface) while the highest value of root length was (11.4 cm) recorded with treatment T7 (70% ETc & burial depth 25 cm). The water use efficiency "WUE" on the total dry biomass basis ranged between 2.11 and 1.494 Kg/m^3 recorded with treatment T6 (70 % ETc & burial depth 15 cm) and T1 respectively, while the corresponding value for water use efficiency "TYWUE" on total yield basis were 17.85 and 12.16 Kg/m^3 recorded with treatment T6 and T10 (55% ETc & burial depth 25 cm). The values of "Ky" ranged between (1.0 and 0.11) recorded with treatments T10 and T6. The yield depression ranged between 47.7 and 0.82 % recorded with treatment T10 and T3 (85 % ETc & burial depth 15 cm) respectively. It is recommended to use the proposed machine for installing drip lines to save time, effort and costs, and to ensure its safety and depth regularity. It is also recommended in tomato cultivation to apply treatment T6 " DIR 70 % ET & burial depth 15 cm", in which the irrigation rate can be reduced by 30% while obtaining the highest water use efficiency and the least relative yield depression (2.34%).

Keywords: Subsurface Drip Irrigation"SDI", Installing machine, Burial depth, Deficit Irrigation regime"DIR", Water Use Efficiency "WUE", Yield Response Factor " Ky", Tomato.

INTRODUCTION

Egypt currently under the water scarcity limit which internationally known as 1000 m^3/capita/year of renewable water resources. This issue may consider the most important challenges for all Egyptian institutions that struggling to cope with water shortages to adequately cover the country: domestic, agricultural, industrial and other basic developmental water needs. Agriculture is the largest sector consuming water in Egypt by 62.15 Billion cubic meter "BCM", representing about 81.22 % of the total water demand 76.3 BCM (CAPMS, 2018). The rationalization of water use in the agricultural sector is one of the most important axes of the National Water Resources Plan prepared by the Ministry of irrigation and water resources through considerable measures, foremost among which is the development of irrigation systems and the operations of modern irrigation systems. Modern irrigation means sprinkler or drip irrigation and subsurface irrigation schemes, and it is applied at the outskirts of the delta and the valley, and the percentage of lands irrigated with modern irrigation in Egypt is reached about two million feddan, and represents 10% of the total irrigated area. Rodríguez and Gil (2012) reported that growing pressure on the world's available water resources has led to an increase in the efficiency and productivity of water-use for irrigation systems as well as the efficiency in their management and operation. The efficiency of subsurface drip irrigation "SDI" could be similar to drip irrigation but it uses less water. It could save up to 25 - 50% of water regarding to surface irrigation. They added that, the wide variety of plants irrigated with SDI all over the world such as herbaceous crops (lettuce, celery, asparagus and garlic), woody crops (citrus, apple trees and olive trees) and others such as alfalfa, corn, cotton, grass, pepper, broccoli, melon, onion, potato, tomato, etc.

Bainbridge (2001) mentioned that historically SDI is one of the oldest modern irrigation methods comes from China more than 2000 years ago, where clay vessels were buried in the soil and filled with water. The water moved slowly across the soil wetting the plants' roots. SDI is defined by Danny et al. (2018) as a type of micro irrigation where water is applied to the crop root zone below the soil surface. Application is by means of small emission points (emitters) at fixed intervals in a series of plastic tubes, which are typically placed either under each row or between crop rows. Reich et al., (2014) reported that, SDI is characterized by low-pressure and high efficiency irrigation system that uses buried drip tubes or drip tape to meet crop water needs. These technologies have been a part of irrigated agriculture since the 1960s; with the technology advancing rapidly in the last three decades. A subsurface system is flexible and can provide frequent light irrigations. This is especially suitable for arid, semi-arid, hot, and windy areas with limited water supply, especially on sandy type soils. Since the water is applied below the soil surface, the effect of surface irrigation characteristics, such as crusting, saturated conditions of ponding water, and potential surface runoff (including soil erosion) are eliminated when using subsurface irrigation. With an appropriately sized and well-maintained system, water application is highly uniform and efficient. Wetting occurs around the tube and water typically moves out in all directions. Also, SDI saves water and improves yield by eliminating surface water evaporation and reducing the incidence of weeds and disease. Water is applied directly to the root zone of the crop and not to the soil surface where most weed seeds germinate after cultivation. As a result, germination of annual weed seeds is greatly reduced which lowers weed pressure on cash crops. In addition, some crops may benefit from the additional heat provided by dry surface conditions, producing more crop biomass and provided water is sufficient in the root zone. When managed properly with a fertilizer injector, water and fertilizer application efficiencies are enhanced, and labor needs are reduced. Field operations are also possible, even when irrigation is applied.

Netafim (2015) stated that, longevity of SDI system depends on factors such as initial water quality, proper operation, regular maintenance and the drip line quality. Netafim has sub-surface drip irrigation systems with more than 20 years of continuous operation. Whereas Camp and Lamm (2003) reported that, some shallow subsurface systems (less than 8-inch depth) are retrieved and/or replaced annually and are very similar to surface drip irrigation. Many research reports refer to these systems as surface drip irrigation, and reserve the term SDI for systems intended for multiple-year use that are installed below tillage depth.

Balas et al. (2018) mentioned that, mechanical as well as manual methods were used for installation and retrieval dripper lines. Farmers have been using manual device for installation and retrieval operations, they were time consuming, laborious, boring, tedious and costly also. These operations need to be done carefully and skillfully to avoid the damages due to folding or twisting of tube during handling and to make the bundle suitable for proper storage. Burt and Barreras (2001) stated that, the handling equipment for fixing and retrieving drip tape is critical for the successful application of drip irrigation “surface or subsurface” to row crops. Commercial tools have been greatly improved in the past ten years; However, it is still very expensive, difficult to operate, and labor-intensive. Rodríguez and Gil (2012) stated that, for installing SDI units in the field, the soil is chiseled to a depth close to the crop roots length prior the layout of laterals. This will also favor the horizontal water movement. Then, the feeding and flushing pipes are laid on trenches dug following the lateral ends keeping an extra space for the connections between pipes and laterals. Once these are done, the other elements such as: valves, relief valves, flow meters can be installed. Finally, all the subsurface elements are buried. Among all the installation tasks, the difficult one corresponds to the deployment of laterals. These are introduced into the soil by one or several plows connected to a tractor. Care must be taking to ensure the laterals are placed following a straight line and at a proper depth, and also that the lateral spacing stays constant. Robert *et al.* (2007) illustrated that, most SDI systems are installed by tractor-mounted, parabolic-shaped injector shanks with mole-or bullet-shaped tips to create a cavity for the tape or tubing. Vibrating shanks are recommended for SDI installations deeper than 20 cm because less horse power is needed, cutting through roots and around rocks is easier, and the cavity around the tubing tends to quickly backfill. Laying or insert the dripper lines with the emitters facing upward will minimize plugging due to particulate accumulations in the bottom of the lines between flushing events and extends the life of the dripper lines. Kinking as well as excessive stretching of the dripper lines must be avoided during installation. NETAFIM (2015) produced number of subsurface insertion machines with a wide variety of auxiliaries tools designed for simple, rapid and efficient installation and removal of dripper lines, while maintaining and avoiding damage to the drippers, enable any grower to install dripper lines in a cost effective and efficient manner. The features incorporated in this tool ensure that the dripper line insertion procedure is done accurately. The use of wear resistant materials guarantees the integrity of the inserted dripper line. A special plastic guide located on the insertion shank will eliminate problems associated with twisted and/or kinked dripper lines. It is impossible to ensure that the drippers will uniformly face upwards. When inserting or laying thick-walled dripper lines. Roller Box with Okolon rollers must be installed on the insertion machine to straighten the dripper lines in order to prevent their bending, ensuring that drippers always face upwards. The dripper line reel must be installed so that it rotates in the opposite direction to the tractor's movement, this way the dripper line enters the conic pipe inlet of the shank at a correct angle.

Tomato (*Lycopersicon esculentum* Mill) is one of the most important horticultural crops in Egypt. Siam and Abdel hakim (2018) reported that tomato is grown in all governorates and throughout the year within the three seasons; winter, summer and Nili (fall). It occupies the first place among horticultural crops in terms of volume of production. The tomato production is 7.7 million tons representing 36% of the total vegetable production in (2015). It occupies the first place in terms of cultivated area with about 469 thousand fed, representing 22.1% of total area of vegetables. The grown area of tomato in the new reclaimed desert land represents about 60% (281.4 thousand fed.). Tomato cultivations in new land are dominated by medium and large-scale farms, in which the application of SDI with tomato cultivations is expected to reduce considerable amount of irrigation water.

Therefore, the hypothesis of the present study was that, developing a simple and inexpensive, drip line installer would greatly benefit and encourage vegetable grower specially tomato to use SDI instead of surface drip irrigation, that will improve water use efficiency and improve crop yield and reduce production costs. The main objective of the current research was to develop a manual steering one row drip lines installing machine and evaluate its performance, efficiency, uniformity and operating costs compared with manual burying. Also, study the effect of using the proposed machine to install T-tape under three levels of deficit irrigation regime and burial depth on tomato plant growth performance and water use efficiency compared with the common practices in tomato plantation in the new reclaimed desert areas.

MATERIALS AND METHODS

Experimental site:

The field experimental work was carried out during summer season of 2019, at a private farm 25 feddan located in 67 km from Cairo–Alexandria desert road, (REGWA project) El-Wady El-Faregh region El-Behara Governorate, Egypt, (30° 11´ N latitude and 30° 35’ E longitude). The soil physical and chemical analysis and the irrigation water well analysis carried out at the soil and water analysis Lab, (underground water Institute, Ministry of Water Supplies and Irrigation, Egypt), as shown in **Table (1, 2 and 3).** The site is characterized by hot or worm in summer and cool in winter, with an average temperature in winter and summer of 14°C and 30°C respectively, and receives less than 80 mm of precipitation annually as in most areas of Egypt, FAO (**2011**).

Table 1. Soil physical analysis of experimental farm.

Very coarse sand %	Coarse sand (%)	Medium sand (%)	Fine sand (%)	Very Fine sand (%)	Silt+ Clay (%)	Soil texture	Field capacity	Wilting point	Saturation (%)
16.6	54.8	1.14	16.48	9.64	1.34	Sandy	12	3.7	29

Table 2. Soil Chemical analysis of experimental farm.

pH	EC(ds/m)	Soluble cations (meq./l)				Soluble anions (meq./l)			
		Ca	Mg	Na	K	CO3	HCO3	Cl	SO4
8.12	1.81	7	3.2	7.6	0.41	Nil	2.5	9	6.71

Table 3. Chemical analysis of experimental water well.

pH	EC(ds/m)	Soluble cations (meq./l)				Soluble anions (meq./l)			
		Ca	Mg	Na	K	CO3	HCO3	Cl	SO4
7.5	4.15	3.6	10.94	76	12.2	Nil	18.4	11.2	15

Development of one row drip line installation machine:

Development considerations:

The manual steering type one row installing machine was developed for small fields, enables one worker to install drip lines. To develop the proposed machine the basic emphasis was given on the following considerations:

1- The development of the proposed machine basically depends on the dimensions of the following items:
   A: Power tiller: Two wheels power tiller 14 hp (model lombardini Italy), **Table (4)** represents the technical specifications of the power tiller.
   B: GR tuber and T-tape reels: The reel dimension in the local market (outer; inner diameter and width) of the common GR tuber were 75, 35 and 35 cm, while T-tape reels were 50; 12 and 38 cm.
2- Simplicity of fabrication, by using locally available material and minimum cost of fabrication.
3- Easy of assembling and dismantling for repair and inspection.
4- Safe in operation and the power requirement of the machine must be within the capacity of the available power tiller.
5- It should install drip lines faster than the existing manual method
6- The machine was developed mainly for small holdings.

Table 4. The technical specifications of the power tiller.

Model	Lombardini 3LD510 Italy
Power, hp	14
Fuel tank capacity, l.	5,3 engine 3 LD 510
Transmission	with oil bath gears
P.T.O. r.p.m.	1028 in clockwise
Tier spacing and diameter, mm	720 spacing, 600 diameter
Gear lever positions	3 forward gears + 1 backward “reverse” gears
Clutch	single dry disc with manual control
Mass, Kg	208

The proposed machine description:

A manual steering one row drip line installation machine mounted on a power tiller 14 hp was fabricated at a small workshop in El-Herafyeen region. As shown in Fig. (1) The machine consists of the following parts:

I- Chassis:

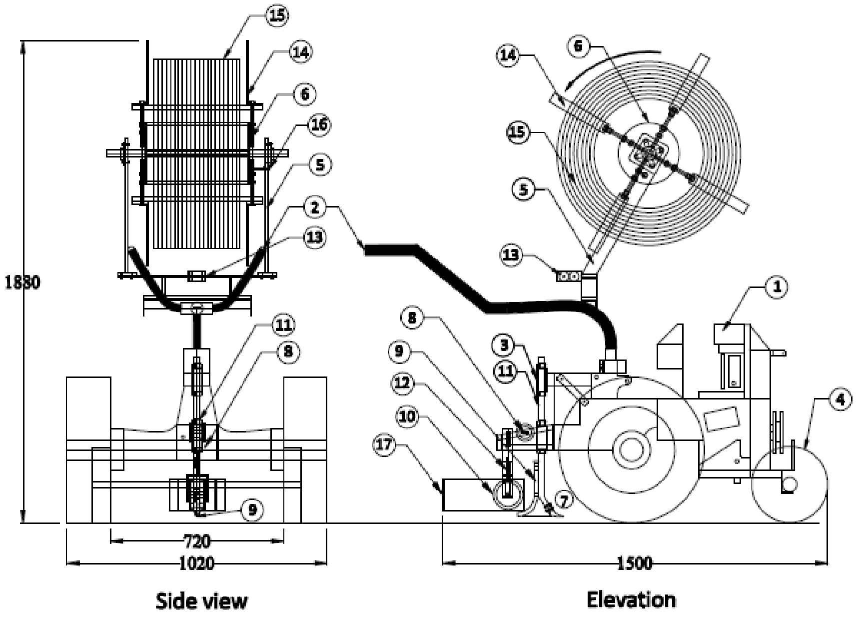
The chassis part (5) was fabricated from angle bare 60x60x6 mm fixed with the handle of the power tiller by welding, to be a carrier of two arms fabricated from flat bar 600x60x6 mm connected with the angle bar at its lower end by two bolts. While the upper end of each arm welded with steel plate 120x60x6 mm to be a carrier of the bearing house. The distance between the two arms could be adjusted to facilitate assembling of spool with the chassis.

II- Spool:

Considering the standard dimensions of the new drip line reels in the local market, two types of spool part (6) were fabricated. The first one for GR tuber, in which the diameter of GR tuber reel ranged between 240 to 350 mm and its width ranged between 300 to 350 mm. A drum with adjustable diameter from 230 mm to 400 mm, consists of two disc 1.5 mm sheet metal with diameter 270 mm., on the quadrant of each disc a flat bar 400x20x12 mm was welded, and at each end of the flat bars there was a stud 14 mm diameter and 160 mm length connected with 20 mm square pipe at the upper end, but the lower end move up and down inside a nut fixed with the disc, so that, adjust the spool outer diameter will be easy. The second spool made from a hollow pipe 3 mm with outer diameter 14 cm especially for T-tape reels. Each spool constructed on a steel shaft (600 x 25mm), the shaft mounted such that it acts as a cantilever having support of the two bearing house (SBR- F205) on each side.

III- Functional parts:

Two rubber wheels (part 4) fixed in front of the power tiller by bolts to maintain its balance. A Chisel 5 cm wide (part 7) can penetrate the soil to a depth ranging from 0.0 to 30 cm depends on a depth adjustment screw (part 11) connected with the hitching point (part 3) of the power tiller used to adjust the chisel height. A Press wheel (part 10) fabricated from mild steel “MS” hollow pipe 3 mm thickness, 180 mm diameter and two circular sheet metal plates 3 mm thickness with 240 mm diameter welded on each side of the hollow pipe that make a grove of 30 mm. Two rigid plastic rollers (part 13) 40 mm diameter suspended on 20 mm free-moving pole that rests on a U-shaped strap 30 mm flat bar welded on the middle of the main chassis to keep the drip lines in the midway of the reel so as to straighten the dripper lines to prevent their bending, ensuring that drippers always face upwards. A guide wheel (part 8) is a simple non-powered, freely rotating wheel fabricated from aluminum (80 mm diameter and 60 mm wide) fixed on a frame fabricated from flat bar (20 x 8 mm) connected with the P.T.O housing to direct the drip line to pass through the guide pipe (part 9) fixed behind the chisel shank, that penetrate the drip line under the press wheel. A tension spring (part 12) adjusts pressure from the press wheel on the soil surface depending on the soil hardness. Soil backfill tool (part 17) fabricated from MS plates 2 mm thickness connected with two arms by two bolts 12 mm with availability to change its level behind the press wheel to backfill the drip line by soil. Four arms of flat bar 80 x 40 x 6 mm bended to L shape, mounted on the quadrant of each side of the spool, used for supporting the reel of drip line. A 50 cm bolt length with Ø 14 mm was fixed with the L shape bracket to be as a suspension lock (part 16) for the reel**. Figure (1)** shows a schematic diagram of the manual steering one row drip lines installation machine. **Figures (2 and 3)** show the proposed machine during installing T-tape and GR respectively in the field.



No.	Part name
1	Power tiller Engine14 hp.
2	Handle
3	Hitching point
4	Balance wheel
5	Chassis
6	Spool
7	Chissel
8	Guide wheel
9	Insertion conic pipe
10	Press wheel
11	Depth adjustment screw
12	Tension spring
13	Two rigid plastic rollers
14	Collapsible bracket
15	Reel of GR tuber 16mm
16	Suspension lock
17	Soil backfill tool
Dim: mm. scale: 1:100	

Fig. 1: Schematic diagram for manual steering one row drip lines installation machine.

Fig. 2: The proposed machine while installing T-tap.

Fig. 3: The proposed machine while installing GR tuber.

Experimental plant:

Tomato seedlings of commercial summer season variety (*Lycopersicon esculentum Mill. cv. Hybrid 23*) were transplanted in the open field at 22 May of 2019 and start harvesting at 31 August of 2019. It used to investigate the effect of both deficit irrigation regime and burial depth on tomato crop performance, and water use efficiency under sandy soil.

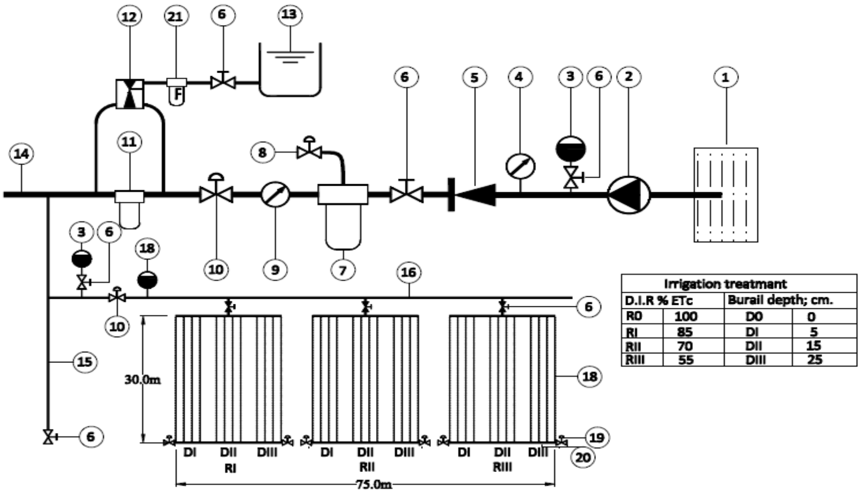
Field tests:

Machine evaluation:

To evaluate the drip line installer compared with the manual method, the machine was tested while installing 12 beds of 30 m long with drip T-tape at the experimental field, 4 beds for each burial depths (5, 15 and 25 cm), and install another 4 beds by GR drip tuber 16 mm with emitter 2 l/h at the soil surface, out of the experimental field. The traveling speed of the machine was kept through all treatments at fixed position 1st gear that give approximately 1.0 km/h without loading. Meanwhile the manual installation was evaluated out of the experimental field depend on four worker crew “two workers for digging and two for burring and backfill drip line by soil”, during installing 12 beds by T-tape 4 beds for each burial depths, and 4 beds by GR drip tuber on the soil surface.

Subsurface drip irrigation evaluation:

The subsurface drip irrigation network was constructed in the experimental area 2250 m^2 (75 m long and 30 m wide) depend on the main components of the irrigation network on the farm “pumping station, filtration unit, main, sub main line “with replacing the GR existing on the soil surface by T-tape 16 mm with emitter 2 l/h installed by using the proposed machine below the soil surface at three burial depth “5; 15 and 25 cm”. The technical specification of the main line was Ø75 mm; sub main Ø 63 mm and manifold Ø 50 mm. The lateral wall thickness was 0.9 mm and the pipe inner diameter was 16 mm and the operating pressure was 1.0 kg/cm^2. The experimental area divided into three main plots; with dimensions of 30 X 25 m, each plot divided into three sub plot each one contains 4 ridges (30 m long and 0.7 m width) the distance between laterals 1.66 and 0.5 m between emitter. There is an interspace 4 m separating the main and sub plots. Irrigation was carried out two times every day throughout the growing season. Drip irrigation was initiated 10 days after transplanting and terminated when 75% of fruits were red or orange. The experimental field was fertilized by 10 m^3 of chicken manure contains “3.2% N, 2.1% P and 1.3% K” as well as 15 kg P_2O_5 /fed., under tomatoes rows through soil preparation. The field irrigated for 6 to 8 hours a day for at least 3 days before transplanting the seedling, to ensure fermentation of fertilizers and avoid any harm on the plants. All other agricultural practices were applied as recommended in commercial tomato production. Layout of the experimental irrigation network and treatment were presented in **Figure (4).** The average amount of water applied to tomato crop (m^3/week/fed) with all treatment was presented in **Table (5).**



Irrigation treatmant			
D.I.R % ETc		Burail depth; cm.	
R0	100	D0	0
RI	85	DI	5
RII	70	DII	15
RIII	55	DIII	25

Fig. 4: Schematic diagram for the experimental subsurface drip irrigation network and treatments. Dim: not to scale.

1	Water source	8	Automatic drainage valve	15	Sub main line
2	Pumping station	9	Water meter	16	Distribution line
3	Air vent	10	Hydraulic valve	17	Vacuum Breaker valve
4	Pressure gauge	11	Secondary filtration unit	18	Dripper line
5	Check valve	12	Dosing unit	19	Flushing valve
6	Manual valve	13	Fertilizer tank	20	Flushing manifold
7	Main filtration unit	14	Main line	21	Fertilize filter

Table 5. Average amount of water applied (m^3/week/fed) with all treatments.

Week	Amount of water applied (m^3/fed)			
	*100 % ETc	85 % ETc	70 % ETc	55 % ETc
1	80	68	56	44
2	85	72.25	59.5	46.75
3	105	89.25	73.5	57.75
4	125	106.25	87.5	68.75
5	150	127.5	105	82.5
6	175	148.75	122.5	96.25
7	195	165.75	136.5	107.25
8	210	178.5	147	115.5
9	230	195.5	161	126.5
10	245	208.25	171.5	134.75
11	265	225.25	185.5	145.75
12	270	229.5	189	148.5
13	180	153	126	99
14	135	114.75	94.5	74.25
15	120	102	84	66
Total amount (m^3/fed)	2570	2184.5	1799	1413.5
Amount of saving (m^3/fed)	--	385.5	771	1156.5

* 100 % ETc (2570 m^3/fed), recommended during 2011 till 2020 by Khalil *et al.* (2016) and Hewady *et al.* (2015).

Experimental design

The experimental layout was a split-plot system in a randomized complete block design with four replications. Where the deficit irrigation treatments were randomly allocated to the main plots and burial depth allocated to the subplot. The average of pooled data was statistically processed with Excel 2010 program. **Table (6)** shows the applied treatments for each plot.

Table 6. Experimental applied treatments.

Treatments	Deficit irrigation regime % ETc.	Burial depth cm
T1*	R0	D0
T2	RI	DI
T3	RI	DII
T4	RI	DIII
T5	RII	DI
T6	RII	DII
T7	RII	DIII
T8	RIII	DI
T9	RIII	DII
T10	RIII	DIII

* T1: (control) or common practices "GR tuber installing at soil surface and irrigation rates 100 % Etc“.

Treatments:

1. Installing methods

a- Installing machine b- Manual

2. Burial depths

a- Soil surface (D0) “control” b- 5 cm (DI) c- 15 cm (DII) and d- 25 cm (DIII)

2.6.3: Deficit irrigation regime

a- 100 % ETc (R0) “control” b- 85% ETc (RI) c- 70% ETc (RII) and d- 55% ETc (RIII)

Data Recorded

1. Data for the machine

The installation time recorded during installing the drip line (T-tape or GR tuber) by the proposed machine or manually included the time for anchoring the ends of drip line at the beginning of each bed, laying two 0.9 m spacing drip line on the soil surface, cutting the drip line at the end of each bed, It took another 4 min to replace the empty reel by a new one, in addition with the time for driving and turning the installing machine to the adjacent beds during testing the machine. On the other hand the time for digging, installing the drip lines and backfill them with the soil were recorded during manual installing. Length of uninstalled drip line (Ru); tangling drip line (Rt) and the damaged or stretching drip line (Rd) in length of 30 m were also recorded. The drip line depths for 18 ridges at each one meter along 30 m were measured.

2. Data for tomato plant growth:

At 90 days after tomato transplanting (DAT), four plants were randomly taken from each subplot for measurement of plant height, root length, total yield and total dry biomass. To measure fresh (FM) and dry (DM) biomass production, each plant was divided into leaf, stem, fruit and root. Roots were extracted from the soil by washing and sieving carefully to minimize the loss of fine roots. Plant component parts were then oven dried for 48 h at 80 °C and weighed, using an electronic balance. At the end of the experiment, plant water use efficiency “WUE” was calculated for each irrigation treatment as the mean ratio of total dry biomass to total plant water use during the experimental period. All harvested total fruits from each subplot at marketable ripe stage along the season were used to determine total marketable yield as Mg/ fed.and total yield water use efficiency “TYWUE“.

Measurements:

Installing machine evaluation:

Installer performance rate (IPR):

The installer performance rate was calculated according to smith *et al.* (1994) by using the following equation:

$$IPR = A/t \quad (fed/h) \text{ ---------- } (1)$$

Where:

IPR= performance rate, fed/h; A =Installing area, fed. ; t = machine operating time, h.

2.8.1.2: Manual installing rate, (M.I.R), fed/h.

$$M.I.R = D.I.R/D.W.T, \quad (fed/h) \text{ ---------- } (2)$$

Where:

D.I.R = daily installing rate; by installing crew = 4 labors, fed/day.

D.W.H = daily working time, h. = 7 h.

Installation efficiency, (η_i), %.

The installation efficiency was calculated according to Mohamed (2017) with some modification, by using the following equation:

$$\text{Installation efficiency } (\eta_i) = 100 - (R_u + R_t + R_d), (\%) \text{ ---------- } (3)$$

Where:

R_u = the percentage of the uninstalled drip line in length of 30 m, (%);
R_t = the percentage of the tangling" kinked or twisted" drip line in length of 30 m, (%);
R_d = the percentage of the damaged drip line or stretching in length of 30 m, (%).

2.8.1.4: Depth Uniformity Index "D.U.I":

The drip line depth uniformity index was estimated by the following equation:

$$D.U.I = 1/CV = d_{av} / \delta d \quad \text{------} (4)$$

Where:

CV= coefficient of variation; d av= average value of the drip line measured depth, cm.
δ d = standard deviation for the measured values of the drip line burial depth.

Fuel consumption: FC.

The rate of fuel consumption with load and without load was estimated according to Suliman *et al.,* (1993) by using the following equation:

$$FC = \frac{f}{t} \times 3.6 \quad \text{------} (5)$$

Where:

FC = fuel consumption, l/h; f = volume of fuel consumption, cm^3 and, t = time, sec.

Power consumption: (P) (KW).

The power consumption was estimate according to Hunt, (1983) by using the following formula:

$$P = \frac{FC \times p_f \times LCV \times 427 \times \eta_{th} \times \eta_{mec}}{3600 \times 75 \times 1.36} \quad \text{------} (6)$$

Where;

P = Power (kW); FC= Fuel consumption, l/h; p_f =Density of fuel, kg /l = 0.85 (for diesel fuel),
LCV= Calorific value of fuel (10000 kcal /kg), 427= Thermo-mechanical equivalent, J/ kcal,
η_{th}= Thermal efficiency of engine (≈ 35% for diesel engines)
η_{mec}= Mechanical efficiency of engine (≈ 80%).

Specific energy: (S.E) (kW.h /fed)

The specific energy was calculated by using the following equation:

$$S.E = \frac{\text{Power requirment (kW)}}{\text{Effective field capacity (fed/h)}} \quad \text{------} (7)$$

Cost analysis:

A comparison between the manual and mechanical installing costs was conducted. The total costs of the installer machine were calculated according to Oida, (1997) by using the follows equations:

$$Tc = \frac{\left\{\left[\left(\frac{Pc-Sv}{Y}\right)+\left(\frac{(Pc+Sv)}{2}\times\frac{i}{100}\right)+(0.02\ Pc)\right]+\left[\left(\frac{Pc\times r_c}{Y}\right)+(fc \times f_p)+(L_c)+(N_l\times L_c\times n_a)\right]\right\}}{n_a} \quad \text{------} (8)$$

Where:

Tc = Total cost, LE/h; D = depreciation = 20 %;
I = annual capital interest taxes ; THI = housing and insurance cost;
R = repair and maintenance cost ; F = fuel cost; LE/h;
Lc = lubrication cost;=14% of fuel cost; L = labor cost; = 150 L.E /day, day(7 hours)
n_a = Annual working hours= h/year= 500
Pc = Machine manufacturing price, L.E; = 4000 L.E; = Power tiller price, = 30000 L.E;
Sv = Salvage value = Pc X S_p , S_p = Salvage percentage $= 56 \times 0.885^n$ for machine and S_p = 68 X 0.92^n ; If
n = machine age upon evaluating = 1 for the machine and 10 for the power tiller; machine, = 29.5 for power tiller.
then; sp = 49.56 % for installer and sp = 29.5 for power tiller
Y = Machine age = 5 years, and 10 years for power tiller; from Mohamed (2017), i = Interest rate =14%;
rc = Coefficient of repair and maintenance = 1 for power tiller, and 0.6 for the installer machine;
fc = Actual fuel consumption = (l/h) ; f p = Fuel price =5.5 L.E = for diesel fuel; N_l = Number of labors = 1 labor.

Costs of manual drip line installation (C. M.I) (L.E/fed).

$$C.\ M.I= [(M.D.C) / D.W.H] / (M.I.R)\ ;\ (L.E/fed) \quad \text{------} (9)$$

Where:

M.D.C = Daily costs of installation crew = no. of worker x worker daily wage L.E/day.
Worker daily wage =150 L.E; then the daily costs of installing crew = 4 x 150 = 600 L.E/h.
D.W.H = Daily working hours = 7 hours; and M.I.R = manual installation rate; fed/h.

Tomato crop measurements:

To evaluate the effect of irrigation treatments on tomato crop performance the following parameter were measured:

1- Growth parameters

- Plant height, cm. - Root length, cm -Total dry biomass, Mg /fed. - Total marketable yield, Mg/fed.

2- Water use efficiency (WUE):

To evaluate the comparative benefits of the different irrigation treatments, WUE were calculated according to Lovelli *et al*., (2007) by the follows equation:

$$WUE = \frac{\text{Average biomass yield (Kg/fed)}}{\text{Total applied irrigation water (m3/fed)}} \ (\text{Kg/m}^3) \text{ --- } (10)$$

3- Total yield water use efficiency (TYWUE):

"TYWUE" Was calculated from the fresh total fruits yield and total water use.by using the following equation:

$$\text{TYWUE} = \frac{\text{Total fresh fruit yield (kg/fed)}}{\text{Total applied irrigation water (m3/fed)}} \ (\text{kg/m}^3) \text{ -------------------------------------- } (11)$$

4- Yield response factor (Ky):

The yield response factor Ky is defined as the decrease in yield "Y" per unit decreases in" ETc" calculated according to Stewart *et al.,* (1977) by using the following equation:

$$(1 - \frac{\text{ETa}}{\text{ETm}})\text{Ky} = (1 - \frac{\text{Ya}}{\text{Ym}}) \text{ -- } (12)$$

Where:

ETm. & Eta.: the maximum (100 % ETc) and actual evapotranspiration, respectively, (m^3/fed).

Ym & Ya: the maximum (from 100 % ETc) and actual yields, respectively, (Mg/fed).

(1– (ETa/ETm)) = the evapotranspiration deficit; and (1 – (Ya/Ym)) = yield depression.

RESULTS

Machine evaluation:

The effect of drip lines installing method and burial depth on the performance rate.

Figure 5. shows the effect of drip lines installing method and burial depth on the performance rate. The highest value of the performance rate was 0.406 fed/h by using the proposed machine to install "GR" drip lines at the soil surface. Meanwhile the performance rate of the manual method during installing "GR" drip lines at the soil surface was 0.314 fed/h. On the other hand, by using both systems (the proposed machine and manual) the performance rate decreases, by increasing the burial depth where the performance rate of the proposed machine during install T-tape decreased from 0.365 to 0.341 and 0.305 fed/h when the burial depth increased from 5 to 15 and 25 cm respectively. Meanwhile the corresponding values of performance rate by using the manual method to install "T-tape" at the same burial depths were 0.241, 0.219 and 0.182 fed/h respectively. It means that, using the proposed machine increase the performance rate by 22.7; 33.97; 35.78 and 40.33 % compared with manual method with increase the burial depth from 0.0; 5; 15 and 25 cm respectively.

The effect of drip line installing methods and burial depth on the installing efficiency.

Figure 6. shows the effect of drip lines installing method and burial depth on the installing efficiency. The highest value of the installing efficiency was 98.81% by using the proposed machine to install the "GR" drip lines at the soil surface. Meanwhile the installing efficiency of the manual method during installing "GR" drip lines at the soil surface was 93.3 %. On the other hand, by increasing the burial depth the installing efficiency decreases by using both systems, where the installing efficiency by using the proposed machine for installing T-tape were decreased from 98.11 to 97.42 and 96.28 %, when the burial depth increased from 5 to 15 and 25 cm respectively. Meanwhile the corresponding values of installing efficiency by using the manual method at the same burial depth were 92.11, 91.56 and 90.16% respectively.

The effect of drip line installing methods and burial depth on the depth uniformity "regularity".

Figures (7 and 8): represent the drip lines depth variation in a relation with installing method and burial depth. The burial depth variation by using the manual method was 4.25 cm recorded at the 1st meter and -4 cm recorded at the last meter along the drip lines with burial depth 25 cm. On the other hand, the corresponding value of the burial depth variation by using the proposed machine was -1.5 cm at the 1st meter and -1 cm at the last meter along the drip lines with burial depth 25 cm. **Table (7)** represent the drip lines average measured depth, coefficient of variation "CV" and depth uniformity index by using the proposed machine and manual installing method. The depth uniformity index ranged between 10.54 and 5.19 recorded with the proposed machine at burial depth 25 and 5 cm. Meanwhile the corresponding values of the depth uniformity index by using the manual method at the same burial depth were 2.902 and 1.31 respectively.

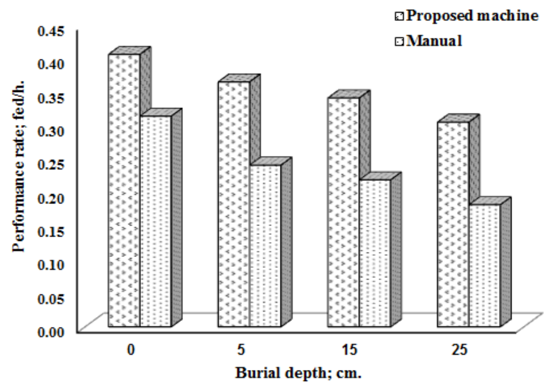


Fig. 5: Effect of installing method and burial depth on performance rate; fed/h.

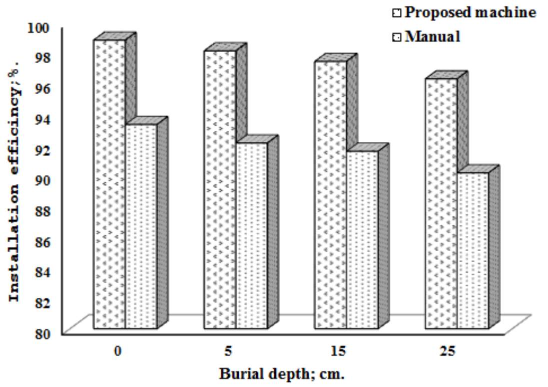


Fig. 6: Effect of installing method and burial depth on installation efficincy; %.

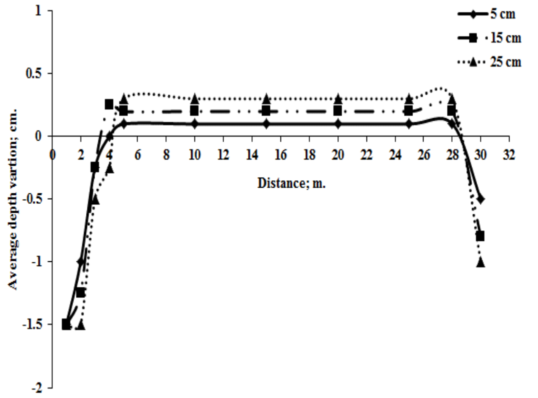


Fig. 7: Drip line depth variation recorded at different burail depth by using the proposed machine.

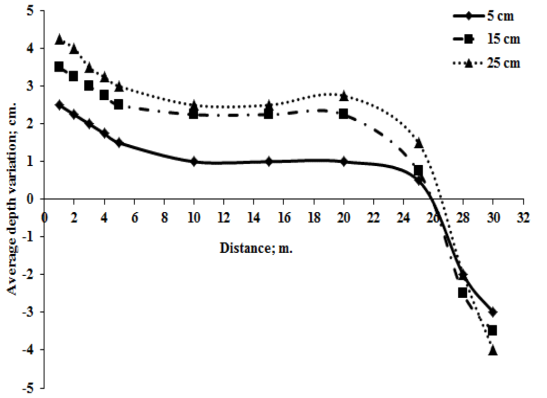


Fig. 8: Drip line depth variation recorded at different burail depth by using manual method.

Table 7: Average measured depth; standard deviation and depth uniformity index calculated for each installing method at each burial depth.

	Installing method					
	Proposed machine			Manual		
Required depth, cm.	5	15	25	5	15	25
Measured depth, cm. Av.	7.74	19.70	29.66	12.1	22.25	32.49
SD.	1.877	2.353	2.814	9.25	10.16	11.196
CV.	0.193	0.119	0.0948	0.764	0.456	0.344
Depth uniformity index.	5.19	8.372	10.54	1.31	2.2	2.902

The effect of drip lines burial depth on the proposed machine fuel consumption.

Figure 9. shows the effect of drip line burial depth on the fuel consumption of the proposed machine. The highest value of the fuel consumption was 0.832 l/h at the burial depth 25 cm. Meanwhile the lowest value of the fuel consumption was 0.681 l/h recorded during installing the drip lines at the soil surface.

The effect of burial depth on the proposed machine power consumption.

Figure 10. shows the effect of drip lines burial depth on the power consumption of the proposed machine. The highest value of the power consumption was 2.303 kW/h.at burial depth 25 cm. Meanwhile the lowest value of the power consumption was 1.885 Kw/h recorded during installing the drip lines at the soil surface.

The effect of burial depth on the proposed machine specific consumed energy.

Figure 11. shows the effect of drip lines burial depth on the specific consumed energy of the proposed machine. The highest value of the specific consumed energy was 7.56 Kw/h/fed at the burial depth 25 cm. Meanwhile the lowest value of the specific consumed energy was 4.81 Kw/h/fed recorded during installing the drip lines at the soil surface.

The effect of drip lines installing method and burial depth on the installation cost.

Figure 12. shows the effect of drip lines installing method and burial depth on the installation costs. The manual installation costs ranged between 469.64 and 258.24 L.E/fed at the burial depth 25 and 0.0 cm ”soil surface” respectively. Meanwhile

the corresponding values of the installation costs by using the proposed machine were 31.52 and 21.37 L.E/fed recorded at the burial depth 25 and 0.0 cm ”soil surface” respectively. It means that, using the proposed machine reduces the installation cost by 93.3 and 91.7 % compared with manual method with the burial depth 25 cm and at the soil surface respectively.

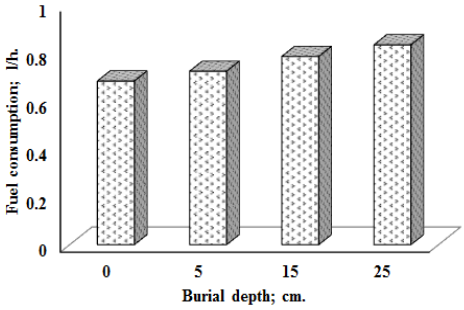


Fig. 9: Effect of burial depth on the proposed machine fuel consumption; (l/h).

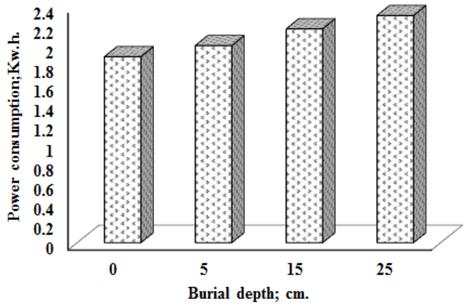


Fig. 10: Effect of burial depth on the proposed machine power consumption;(Kw.h).

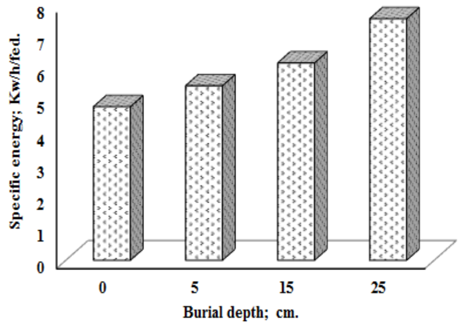


Fig. 11: Effect of burial depth on the proposed machine specific energy; (Kw.h/fed).

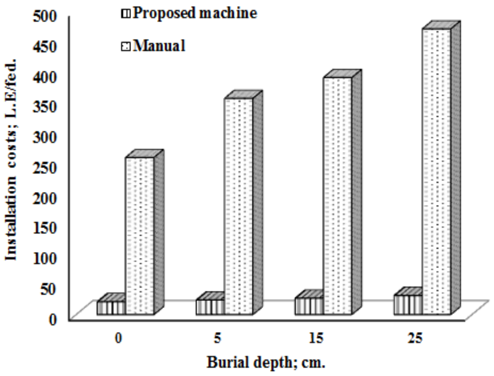


Fig. 12: Effect of installing method and burial depth on installation costs; L.E/fed.

Tomato plant growth performance evaluation:

Effect of deficit irrigation regime “DIR” and burial depth on tomato plant height.

Figure 13. shows the effect of deficit irrigation regime “DIR” and drip line burial depth on the plant height. The highest values of the plant height were 68.53 and 68.41 cm. recorded with treatments T3, T6 when the drip lateral placed on burial depth 15 cm with 85 and 70 % deficit irrigation respectively. Meanwhile the lowest values of plant height were 44.81 and 45.73 cm. recorded with treatments T10 and T8 in the case of DIR 55 % with the drip lateral placed on burial depth 25 and 5 cm respectively. On the other hand the plant height recorded with the control treatment T1 was 68.83 cm.

Effect of DIR and burial depth on tomato plant root length.

Figure 14. shows the effect of deficit irrigation regime “DIR” and drip line burial depth on the plant root length. The highest values of the root length were 11.4 and 11.2 cm recorded with treatments T7 and T6 in the case of the drip lateral placed on burial depth 15 cm with 85 and 70 % deficit irrigation respectively. Meanwhile the minimum values of the plant root length were 7.3 and 7.8 cm recorded with treatments T8 and T9 in the case of DIR 55 % with the drip lateral placed on burial depth 5 and 15 cm respectively. On the other hand, the value of the plant root length recorded with the control treatment T1 was 8.65 cm.

Effect of DIR and burial depth on tomato plant total dry biomass.

Figure 15. shows the effect of deficit irrigation regime “DIR” and drip line burial depth on the plant total dry biomass. The highest values of the total dry biomass were 3.81 and 3.79 Mg/fed recorded with treatments T3 and T6 in the case of the drip lateral placed on burial depth 15 cm with 85 and 70 % deficit irrigation respectively. Meanwhile the lowest values of plant total dry biomass were 2.66 and 2.79 Mg/fed recorded with treatments T10 and T8 in the case of DIR 55 % with the

drip lateral placed on burial depth 5 and 25 cm respectively. On the other hand, the plant total dry biomass recorded with the control treatment T1 was 3.84 Mg/fed.

Effect of DIR and burial depth on tomato total marketable yield.

Figure 16. shows the effect of deficit irrigation regime "DIR" and drip line burial depth on the plant total marketable yield. The highest values of the total marketable tomato yield were 32.61 and 32.11 Mg/fed recorded with treatments T3 and T6 in the case of the drip lateral placed on burial depth 15 cm with 85 and 70 % deficit irrigation respectively. Meanwhile the lowest values of total marketable tomato yield were 17.2 and 18.41 Mg/fed recorded with treatments T10 and T8 in the case of DIR 55 % with the drip lateral placed on burial depth 5 and 25 cm respectively. On the other hand, the total marketable tomato yield recorded with the control treatment "T1" was 32.88 Mg/fed.

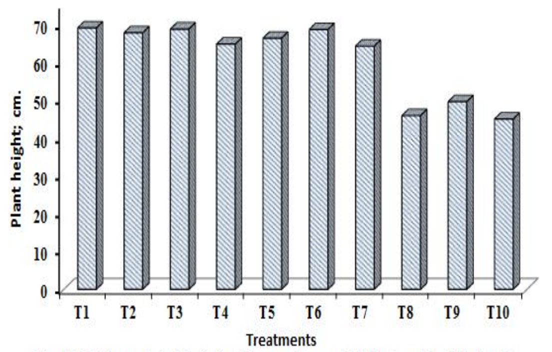


Fig. 13: Effect of deficit irrigation regime and drip lines burial depth on tomato plant height; cm.

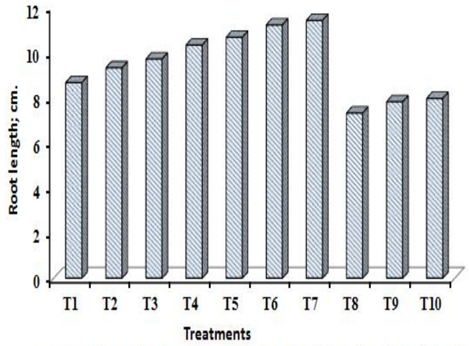


Fig. 14: Effect of deficit irrigation regime and drip lines burial depth on tomato plant root length; cm.

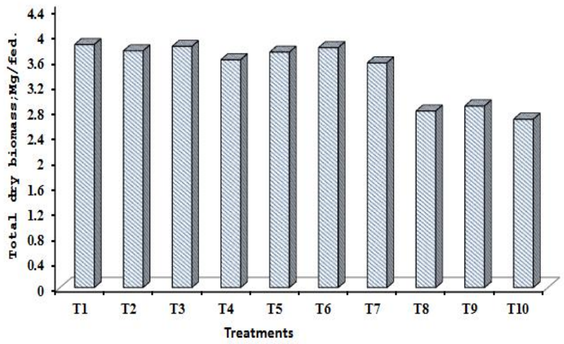


Fig. 15: Effect of deficit irrigation regime and drip lines burial depth on tomato total dry biomass; Mg/fed.

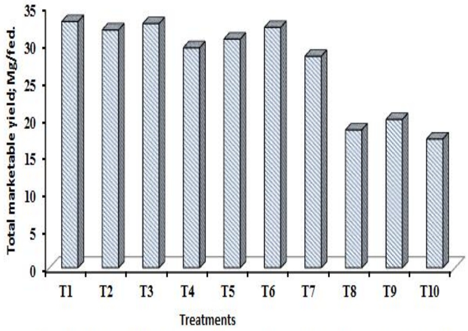


Fig. 16: Effect of deficit irrigation regime and drip lines burial depth on tomato total marketable yield; Mg/fed.

Effect of DIR and burial depth on tomato plant water use efficiency "WUE".

WUE calculated on the total dry biomass basis. **Figure 17.** shows the effect of deficit irrigation regime "DIR" and drip line burial depth on the plant water use efficiency. It is clear that, the highest value of the water use efficiency "WUE" was 2.11 Kg/m^3 recorded with treatment T6 in the case of applying DIR 70 % ET with burial depth 15 cm. Meanwhile the lowest values of the water use efficiency "WUE" was 1.494 Kg/m^3 recorded with the control treatment T1 (100% ETc at the soil surface).

Effect of DIR and burial depth on tomato plant total yield water use efficiency "TYWUE".

TYWUE was calculated on the total yield basis. **Figure 18.** shows the effect of deficit irrigation regime "DIR" and drip line burial depth on the total yield water use efficiency. It is clear that, the highest value of "TYWUE" were 17.85 Kg/m^3 recorded with treatment T6 in the case of drip line burial depth was 15 with DIR 70%. Meanwhile the lowest value of the total yield water use efficiency "TYWUE" was 12.16 Kg/m^3 recorded with treatment T10, in the case of drip line burial depth was 25cm with DIR 55%. On the other hand, TYWUE value recorded with the control treatment T1 was 14.60 Kg/m^3.

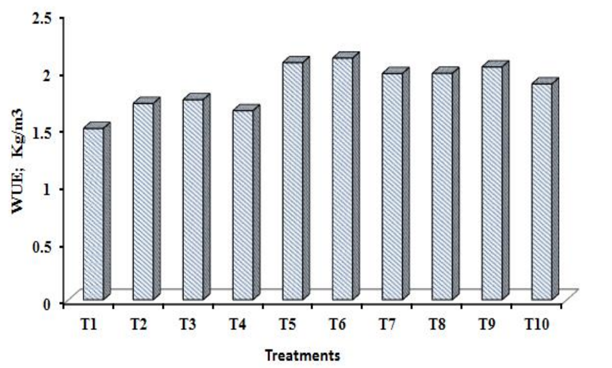


Fig. 17: Effect of deficit irrigation regime and drip lines burial depth on water use efficiency "WUE"; Kg/m3.

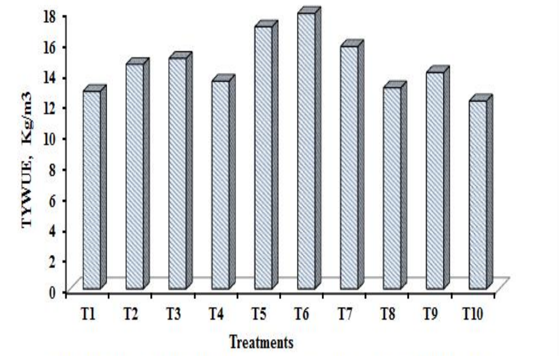


Fig. 18: Effect of deficit irrigation regime and drip lines burial depth on total yield water use efficiency "TYWUE"; Kg/m3.

Effect of DIR and burial depth on tomato yield response factor "Ky" and yield depression.

Yield response factor Ky in this study was calculated for the total marketable yield. Figure 19. shows the effect of deficit irrigation regime "DIR" and drip line burial depth on tomato yield response factor. It's clear that, there is a direct relationship between yield response factor "Ky" and DIR at the same burial depth, where Ky increased from 0.22 to 0.23 and 0.97 while DIR decreased from 85 to 70 and 55 % ETc at the same burial depth 5 cm. The highest value of Ky were 1.0 recorded with treatment T10, in case of the applied DIR was 55 % ETc and burial depth 25. Meanwhile the lowest value of Ky were 0.11 recorded with treatments T3 and T6, when the applied burial depth was 15 cm with DIR 85 and 70 % ETc.

Figure 20. represent the effect of DIR % and burial depth on tomato total yield depression %. It is clear that, there is a direct relationship between the yield depression with ETc reduction at the same burial depth, where the yield depression increased from 3.38 to 7.14 and 44 % when the reduction of DIR increased from 15 to 30 and 45 %. The highest values of yield depression were 47.7 % recorded with treatment T10 when reducing ETc by 45 %, with burial depth 25 cm. Meanwhile the lowest values of yield depression were 0.82 % recorded with treatment T3 when ETc reduced by 15 with burial depth 15 cm. It is recommended to apply treatment T6 in which the yield depression was 2.34 % with reduction in ETc by 30 %.

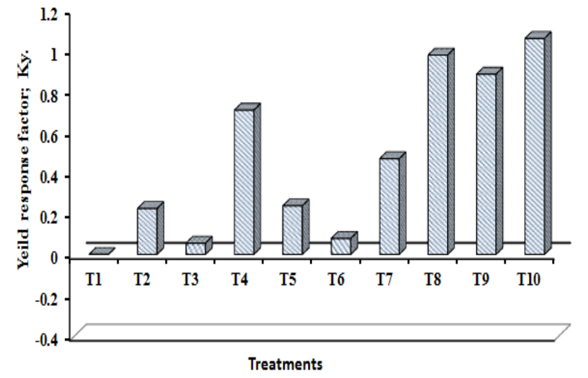


Fig. 19: Effect of deficit irrigation regime and drip lines burial depth on tomato yield responce factor; Ky.

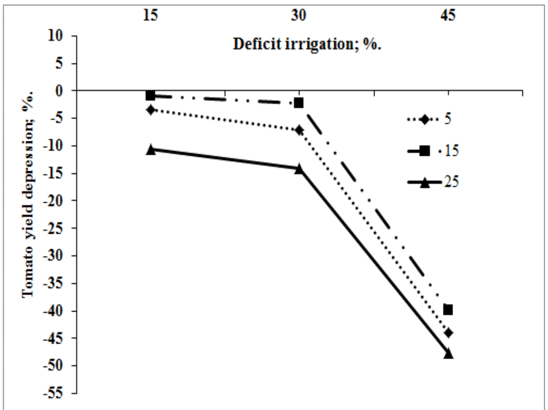


Fig. 20: The effect of deficit irrigation % and burail depth on tomato yield depression; %.

DISSCUSION

The results of this study revealed that using the proposed machine improve the performance rate, installation efficiency and uniformity of drip lateral depth compared with manual installing method, the maximum performance rate of the proposed machine and manual method were 0.406 and 0.314 fed/h respectively. Using the proposed machine reduce the installation cost by 93.3 % compared with the manual installation. These results recorded during install drip lines for field containing 30 m long bed and 1.66 m lateral spacing and the machine traveling speed was 1 Km/h without load. These results are less than those obtained by Zhu *et al.* (2004) with a simple drip tape installer and retriever in the same unit for surface drip irrigation applications, the performance rate of this machine was 1.98 fed/h, because it has three rows, for a field containing 91 m long beds with 0.91 m lateral spacing, when the tractor travel speed was 6.4 km/h. Mansour *et al.,* (2019) comparing three systems for installing drip line, manual surface "M"; semi mechanized subsurface "SM", and QRM machine in relation with production costs of corn crop. The SM and QRM improved the maize yield and Stover production, net profit, and the physical income. The net income of the economic unit of irrigation water used as ($ /m^3) was 50 and 51 by using sub-surface irrigation SM and QRM methods compared to the manual surface drip. Also this net income as (kg/m^3) was increased by 6.6% and 5.2% with subsurface drip SM method and QRM method relative to surface drip irrigation system QRM machine. As far the tomato plant growth performance the highest value of plant height was 68.83 cm, total dry biomass was 3.84 Mg/fed and total marketable yield was 32.88 Mg /fed recorded with treatment T1 (100% ETc & at soil surface) while the highest value of root length was 11.4 cm recorded with treatment T7(70 % Etc & burial depth 25 cm). These results agree with Kekere *et al.,* (2020) where the max plant height and root length was 97.3 cm and 10.9 cm. on the other hand, Aboamera *et al.* (2008) stated that the best distribution of roots was observed with 30 cm of emitter spacing and 20 cm depth of lateral line. Machado, *et al.,* (2003) evaluated tomato yield in a 2-year field trial where surface drip irrigation (R0) was compared with subsurface drip irrigation at 20 cm (RI) and 40 cm (RII) depth. Commercial yields were 36.8 and 47.9 Mg/fed (R0), 45.2 and 53.8 Mg/fed (RI), 44.1 and 52.4 Mg/fed (RII). Patel and Rajput (2009) found that, onion yield was significantly affected by the placement depth of the drip lateral. The highest yield was (10.8 Mg/fed) with burial depth 10 cm. The lowest yield was (6.3 Mg/fed) recorded with burial depth 30 cm and 40% deficit irrigation. The water use efficiency "WUE" ranged between 2.11 and 1.494 Kg/m^3 recorded with treatment T6 (70 % ETc & burial depth 15 cm) and T1 (100 % ETC & burial depth 0.0 cm), while the corresponding value for TYWUE were 17.85 and 12.16 Kg/m^3 recorded with treatment T6 (70 % ETc & burial depth 15 cm) and T10 (55% ETc & burial depth 25 cm). The highest value of yield response factor "Ky" was 1.0 recorded with treatment T10. The yield depression ranged between 47.7 and 0.82 % recorded with treatment T10 and T3 (85 % ETc & burial depth 15 cm). In this regard, Singh *et al*. (2010) mentioned that yield response factor may be considered as an index of crop tolerance to water stress (the lower the index, the greater the tolerance).These results agree with the obtained results by Patel and Rajput (2009) where the maximum irrigation water use efficiency (IWUE) for onion crop was 23.1 Kg /m^3, obtained by placing the drip lateral at 10 cm depth. While Aboamera et al. (2008) found that the highest value of tomato water use efficiency was 44.39 kg/m^3 recorded when the lateral line lied at the soil surface with 30 cm of emitter spacing. Although complete irrigation (100% ETc) of the tomato crop by using GR tuber at the soil surface maximize the plant growth performance, using T-tape with applying treatment with DIR 85 or 70 % ETc and burial depth 5 and 15 cm improve the water use efficiency (WUE and TYWUE) with acceptable yield depression, due to the vertical movement of water in sandy soil that occurs because of the predominant role of gravity rather than that of the capillary forces, and also the main and secondary hair roots of tomato plant concentrated at 15 cm depth. It is recommended in tomato cultivation to apply treatment T6 "70 % ETc & burial depth 15 cm", in which the irrigation rate can be reduced by 30% while obtaining the highest water use efficiency and the least relative yield depression (2.34%).

CONCLUSION

Conclusion from the previous results can be summarized as follows:

1- Using the proposed machine improve the performance rate, installation efficiency and drip lateral depth uniformity compared with manual installation. For a field containing 30-m long beds with 1.6 m lateral spacing and the power unit traveling speed 1.0 km/h. the maximum performance rate of the proposed machine and manual method at the recommended burial depth 15 cm was 0.406 and 0314 fed/h, respectively.

2- Using the proposed machine reduce the installation cost by 93.3 % compared with the manual method. The maximum installation costs by using the proposed machine and manual method were 31.52 and 469.64 L.E/ fed at a burial depth of 25 cm.

3- Full irrigation (100% ETc) by using GR tuber at the soil surface maximizes tomato plants growth performance and fruit yield, but applying treatment T6 gives the highest value of (WUE and TYWUE) and lowest value of relative yield depression (2.34 %) with water rationalize of 30 %. Therefore, applying treatment T6 with DIR of 70% and placing T tape at a depth of 15 cm, advisable for tomato plantation in the new reclaimed desert land.

Recommendations:

1- The prototype of the proposed machine is developed mainly for small holdings, so that, further modification must be conducted to the machine functional parts to facilitate retrieving "winding" the drip lines as well as improving its performance, durability, and economic feasibility with large fields

2- To encourage growers to apply subsurface drip irrigation system and expanded its benefit, it is necessary to manufacture the proposed machine for drip lines installation on a commercial scale to reduce its price, in which it is characterized by low costs, simplicity of operation, and regularity of drip line, compared with manual method.

3- Applying SDI system with tomato growing area at the new reclaimed desert land "281.4 thousand fed"may help to save 30 % ET "2570 m^3/fed". from the amount of irrigated water that represent about 217 million m^3 per season, " 651 million m^3 annually" where it is grown throughout the year within three seasons; winter, summer and Nili (fall), can be used to fill the deficit in irrigation water to grow other strategic crops.

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تطوير آلة لتركيب صف واحد من خطوط الري تحت السطحى وتأثيرها على إنتاج الطماطم

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الملخص العربى

أجريت هذه الدراسة بمزرعة خاصة تقع عند الكيلو 67 من طريق القاهرة الأسكندرية الصحراوى بمشروع ريجوا بمنطقة الوادى الفارغ بمحافظة البحيرة، وذلك لتطوير وإختبار آلة مقترحة صنعت محليا بورشة صغيرة فى منطقة الحرفيين، تستخدم فى تركيب خطوط الرى بالتنقيط تحت السطحى بهدف تقييم آداء الآلة المقترحة وكفاءة وتكاليف تشغيلها، و مؤشر إنتظام عمق الخطوط مقارنة بالطريقة التقليدية ، وكذلك دراسة تأثير استخدام "T-tape" وتطبيق ثلاث معدلات خفض فى ماء الرى عن المعدل الموصى به وهو (2570 م^{3} /فدان) إلى 85 % و 70 و55 % على إمتداد موسم النمو ، مع ثلاث أعماق دفن لخطوط الرى (5 و 15 و 25 سم) مقارنة بالمعاملة الحاكمة وفيها توضع خراطيم "RG" فوق سطح التربة مع معدل رى (100 ETc%) على سلوك النمو لنباتات الطماطم وتشمل: إرتفاع النبات، وطول الجذر، إجمالى الكتلة الحيوية الجافة، إجمالى محصول الثمار القابل للتسويق، كفاءة إستخدام المياه، إلى جانب معامل إستجابة المحصول، ويمكن تلخيص نتائج الدراسة كما يلى:

أولا: نتائج تقييم الآلة المقترحة مقارنة بالطريقة التقليدية:

1- أعلى قيمة لمعدل الآداء كانت 0.406 فدان/ساعة عند استخدام الآلة المقترحة فى وضع خراطيم ال "RG"على سطح التربة، بينما كان معدل آداء الطريقة التقليدية عند وضع خراطيم الرى "GR"على سطح التربة 0.314 فدان/ ساعة .ويقل معدل آداء الآلة المقترحة عند وضع "T-tape " على أعماق 5 و 15 و 25 سم إلى 0.365 و 0.341 و 0.305 فدان/ ساعة على الترتيب، فى حين قل معدل آداء الطريقة التقليدية عند وضع "T-tape"على نفس الأعماق إلى 0.241 و 0.219 و 0.182 فدان/ساعة على الترتيب.

2- أعلى قيمة لكفاءة تركيب خطوط الرى بالآلة المقترحة كانت 98.81 % عند وضع خطوط "RG"على سطح التربة ، وتقل قيمة كفاءة التركيب إلى 96.16 % عند وضع خطوط "T-tape "على عمق 25 سم . فى حين كانت القيمة المقابلة لكفاءة التركيب بالطريقة اليدوية 93.3 عند وضع خطوط "RG"على سطح التربة و90.16 % عند وضع خطوط الرى من نوع "T-tape "على عمق 25 سم.

3- تراوحت قيم مؤشر انتظامية عمق خطوط الرى مع استخدام الآلة المقترحة بين 5.2 ، 8.4 و 10.5 عند وضع خطوط الرى على عمق (5،15 و 25 سم) على الترتيب ، بينما كانت القيم المناظرة مع استخدام الطريقة التقليدية 1.3 ، 2.2 و 2.9 .

4- تراوحت قيمة إستهلاك الوقود للآلة المقترحة بين 0.832 - 0.681 ل/ساعة عند وضع خطوط الرى على عمق 25 سم وعلى سطح التربة على الترتيب.

5- أعلى قيمة لإستهلاك الطاقة كانت 2.303 كيلوات/ساعة عند التركيب على عمق 25 سم بينما كانت أقل قيمة لإستهلاك الطاقة 1.885 كيلوات /ساعة عند التركيب على سطح التربة.

6- أعلى قيمة لإستهلاك الطاقة النوعي كانت 7.56 كيلوات/ساعة/فدان عند التركيب على عمق 25 سم بينما كانت أقل قيمة لإستهلاك الطاقة 4.81 كيلوات /ساعة/فدان عند التركيب على سطح التربة.

7- تراوحت تكاليف تركيب خطوط الرى باستخدام الآلة المقترحة بين 31.52 و 21.37 جنيه/فدان على عمق 25 سم وعلى سطح التربة على الترتيب ، بينما القيم المقابلة لتكاليف وضع خطوط الرى مع استخدام الطريقة اليدوية كانت 469.64 و 258.24 جنيه/فدان على الترتيب عند نفس الأعماق.

ثانيا: نتائج تقييم آداء النمو فى نبات الطماطم:

1- أعلى قيمة لطول النبات كانت 68.53 سم سجلت عند المعاملة "T3" ، بينما أقل قيمة لطول النبات كانت 45.73 سم سجلت عند المعاملة "T10" فى حين كانت قيمة طول النبات 68.83 سم عند المعاملة الحاكمة "T1".

2- أعلى قيمة لمتوسط طول الجذر كانت 11.4 سم سجلت عند المعاملة "T7" ، بينما أقل قيمة لطول الجذر كانت 7.3 سم سجلت عند المعاملة "T8" فى حين كان متوسط طول الجذر 8.65 سم عند المعاملة الحاكمة "T1" .

3- أعلى قيم للكتلة الحيوية الكلية الجافة كانت 3.81 ميجا جرام/فدان سجلت عند المعاملة "T3"، بينما أقل قيمة للكتلة الحيوية الكلية الجافة كانت 2.66 ميجا جرام/فدان سجلت عند المعاملة "T10" فى حين كانت قيمة الكتلة الحيوية الكلية الجافة 3.84 ميجا جرام /فدان عند المعاملة الحاكمة "T1" .

4- أعلى قيمة لمحصول الطماطم الكلى القابل للتسويق كانت 32.61 ميجا جرام/فدان سجلت عند المعاملة "T3" ، بينما أقل قيمة كانت 17.2 ميجا جرام/فدان سجلت عند المعاملة "T10"، فى حين كانت قيمة محصول الطماطم الكلى القابل للتسويق عند المعاملة الحاكمة "T1" 2.88 ميجا جرام /فدان.

5- أعلى قيمة لكفاءة استخدام الماء محسوبة على أساس إجمالي الكتلة الحيوية الجافة كانت 2.11 كجم/م^3 سجلت عند المعاملة ”T6“ بينما أقل قيمة لكفاءة استخدام الماء بناءا على الكتلة الحيوية الكلية الجافة كانت 1.494 كجم/م3 سجلت عند المعاملة الحاكمة ”T1“.

6- أعلى قيمة لكفاءة استخدام الماء محسوبة على أساس المحصول الكلى كانت 17.85 كجم/م^3 سجلت عند المعاملة ”T6“ . بينما أقل قيمة لكفاءة استخدام الماء بناءا على إجمالى المحصول الكلى كانت 12.16 كجم/م^3 سجلت عند المعاملة ”T10“ فى حين كانت قيمة كفاءة استخدام الماء على أساس إجمالى المحصول 14.6 كجم/م^{3}عند المعاملة الحاكمة ”T1“.

7- أعلى قيمة لمعامل إستجابة المحصول كانت 1.0 سجلت مع المعاملة ”T10“ (عند معدل خفض للرى 55 % وعمق خطوط الرى 25 سم) والتى معها كانت نسبة إنخفاض المحصول 47.7 % ، بينما أقل قيمة لمعامل إستجابة المحصول كانت 0.11 سجلت مع المعاملة ”T3“ (عند معدل خفض للرى 85 % وعمق خطوط الرى 15 سم) عندها كانت قيمة إنخفاض المحصول 0.83 % .

8- على الرغم من أن الرى الكامل (100٪ ETc) لمحصول الطماطم كما فى المعاملة الحاكمة ”T1“ باستخدام خراطيم ”GR“ على سطح التربة يؤدى إلى تعظيم أداء نمو النبات والمحصول الناتج ، إلا أنه ينصح بتطبيق المعاملة ”T6“ بمعدل خفض ماء الرى 70 % ETc وإستخدام ”T-tape“ عند منطقة الجذور" 15 سم"، وذلك لأنه يمكن تخفيض معدل الرى بنسبة 30 % والحصول على أعلى كفاءة فى استخدام المياه مع أقل فقد نسبى فى المحصول (2.34 %).

التوصيات

1- النموذج الأولى للآلة المقترحة معد للحيازات الصغيرة، لذا يجب إجراء المزيد من التعديلات على الأجزاء الوظيفية للآلة المقترحة لتسهيل إستخدامها فى تركيب وإسترجاع "لف" خطوط الرى بالتنقيط وكذلك تحسين الأداء والمتانة والجدوى الاقتصادية حتى تتناسب مع الأستخدام فى المساحات الكبيرة.

2- لتشجيع المزارعين على تطبيق نظام الري بالتنقيط تحت السطحى، يوصى بتصنيع الآلة المقترحة على نطاق تجاري لخفض سعرها، حيث تمتاز بقلة التكاليف وبساطة التشغيل وإنتظام العمق وسلامة الخطوط مقارنة بالطريقة اليدوية.

3- يؤدى تطبيق نظام الرى تحت السطحى المقترح SDI فى المساحة الكلية لمحصول الطماطم بالأراضى الصحراوية المستصلحة "281.4 ألف فدان" إلى توفير 30٪ ETc من كمية ماء الرى التي تمثل حوالي 217 مليون متر مكعب في الموسم "651 مليون متر مكعب سنويًا" حيث تتم زراعتها على مدار العام خلال ثلاثة مواسم، الشتاء والصيف والنيلي (الخريف)، وهذا القدر يمكن استخدامه لسد النقص في مياه الري اللازمة لزراعة المحاصيل الاستراتيجية الأخرى.

الكلمات المفتاحية: الرى بالتنقيط تحت السطحى، آلة تثبيت خطوط الرى، عمق الدفن، نظام الرى الناقص، كفاءة استخدام المياه، معامل استجابة المحصول، الطماطم.