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Evaluation of Trickle Irrigation Performance and its Moisture Distribution in Clay Soil

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Abstract **- One of the best solutions to solve the water scarcity in Egypt is using modern irrigation system in old land (converting surface irrigation to modern irrigation), A field experiment was carried out in open field conditions in clay soil at Agricultural Research Centre in Giza Governorate during 2021- 2022 to study the effect of using two types of trickle irrigation systems (GR and T-tape) on the productivity of the maize crop kg/fed., through studying the moisture distribution, Emission uniformity%, flow rate variation l/h, water applied m^3/fed and water productivity kg/m^3 to help the farmers in selecting the proper irrigation system and its equipment and to guide them for managing their systems. The results declared the followings:**

With trickle irrigation system under GR treatments, the yield and water productivity decreased with increased of depth of lateral line in the soil while under T-tape irrigation system the yield and water productivity under the soil depth (10cm and 20cm) was higher than the surface T-tape and the T-tape under depth of soil (30cm) and the emission uniformity increased with the surface T-tape irrigation system compared with surface GR irrigation system. The coefficient uniformity and distribution uniformity were higher in the beginning of growing season than the end of growing season due to the variation in the flow rate. Generally, with T-tape irrigation system, the emission uniformity, the yield, and water productivity increased compared to GR irrigation system under all depths of lateral line in the soil

Keywords: Trickle irrigation system (GR and T-tape), moisture distribution, irrigation water productivity, water applied.

I. INTRODUCTION

Maize crop is the most widespread summer crop and has global importance. It is considered the third most important crop in the world after wheat and rice in terms of economic importance. It is also described as a fodder plant with high nutritional value for all types of animals; in addition to that it is used in mixing and improving soil properties by adding organic matter as well. It is a complete food that contains all nutrients for milk and fattening animals.

Sustainable water use has become a major concern in agriculture and irrigation. The adoption of strategies for conserving irrigation water and maintaining acceptable yields may contribute to the preservation of this increasingly restricted resource (Toscano et al. 2014). The total amount of available water in Egypt is, 55.5 milliard m3/year and the sector of agriculture consume about 85% of the total available water (Elshafei, and Seleym2017). Morad et al. (2020). Study the irrigation management for maize crop in sandy soil with three types of emitters (GR, antiroot GR, and T-tape) this study showed that the best treatment was using compost with antiroot GR sub-surface trickle system, which gave the best yield. Using compost with t-tape sub-surface trickle system gave good yield but using compost with antiroot GR sub-surface trickle system gave the best yield. Water management and use are a continuing problem in developing countries with semi-arid to arid climates such as Egypt. According to Mohendran et al. (2013) subsurface irrigation is an excellent way to deliver water and nutrients to plant roots since water is given directly to the productive root zone of crops in the subsoil layer. The subsurface trickle irrigation technique required less water than surface irrigation since the water loss was minimal. Abdel-Aal and Hassan (2013) conducted astudy to determine the irrigation efficiency, water saving, cowpea yield, yield components, water productivity and net profit for traditional, trickle and subsurface irrigation systems in sandy soil conditions, the experimental results revealed that, the application efficiency; distribution uniformity and irrigation efficiency for subsurface irrigation increased by 4.2, 13.5 and 60.1%, 47.57, 15.97 and 8.99, 31.70 and 109.75% compared with trickle, sprinkler and traditional systems. Trickle systems increased the pod yieldand water productivity (WUE) by 14.98 and 9.47%, 40.42 and 57.58% and 61.76 and 188.89% compared with subsurface, sprinkler and traditional systems.

There are number of studies tackling the soil water Content distribution for both, surface and subsurface trickle irrigation most of them from deterministic approaches. A detailed description of the most relevant theories for predicting soil water dynamics during trickle irrigation can be found in Subaiah (2013) and specific examples for surface and subsurface systems are in Knowing how water behaves in vertical and horizontal directions along the soil profile is important in terms of meeting optimum plant water requirement and efficient water use. As a result of the restriction of the lateral movement of water due to the negative pressure under the ground, deep percolation or wetting of the soil surface may occur. This situation reduces the efficiency of surface trickle irrigation systems (Rodríguez Sinobas et al., 2021; Appels and Karimi, 2021). Ibrahim and Soliman(2022) showed that the amount of land planted with maize in Egypt varied between two limits, with the lowest amounting to roughly 1657.8 thousand acres in 2003 and the highest amounting to roughly 2335.63 thousand acres in 2018.The objective of this study is mainly to study the effect of using trickle irrigation systems(GR and T-tape) on productivity, moisture distribution, Emission uniformity %, flow rate variation l/s, water applied m3/fed, and water productivity kg/m3 in the Clay soil field to help farmers that work on converting surface irrigation to modern irrigation to choose the appropriate irrigation system and guide them to manage their systems.

II. MATERIALS AND METHODS

A field experiment was conducted under open field conditions in clay soil at the Agricultural Research Center in Giza Governorate during season 2021-2022. The trickle irrigation system (GR and T-tape) was tested to evaluate its suitability for maize cultivation using eight treatments that include two different type of trickle system (GR and T-tape).

To evaluate the irrigation system in the clay soil; eight treatments were used in the experiment as listed in Table (1) where four treatments of trickle irrigation system (GR) with flow rate 4 l/h under operating pressure 1.0bar and space between the emitter 50 cm while another four treatments of trickle irrigation system (T-tape) with flow rate 8 l/h/ for one meter under operating pressure 1.0bar, and table (2) indicates the specifications of the GR lateral lines (outlet diameter) and table (3) indicates the specifications of T-tape lateral lines.

TABLE 1. THE TREATMENTS OF GR AND T-TAPE IRRIGATION SYSTEM.

System of irrigation	GR				T-tape			
Depth under surface (cm)	On top the surface	10 cm under the soil	20 cm under the soil	30 cm under the soil	On top the surface	10 cm under the soil	20 cm under the soil	30 cm under the soil
Treatments	GR0	GR10	GR20	GR30	TP0	TP10	TP20	TP30

TABLE 2. SOME CHARACTERISTICS FOR LATERAL LIENS (GR).

Specification of the lateral lines						
Commercial name	Manufactory country	Spacing between laterals (cm)	Spacing between emitters (cm)	Length of lateral line (m)	Nominal diameter for lateral line (mm)	Flow rate (1/h)
GR	Egypt	80	50	50	16	4.00

TABLE 3. SOME CHARACTERISTICS FOR LATERAL LIENS T-TAPE.

Specification of the lateral lines					
Commercial name	Manufactory country	Spacing between laterals (cm)	Length of lateral line (m)	Nominal diameter for lateral line (mm)	Flow rate (1/h/m)
T-tape	Egypt	80	50	16	8.00

TABLE 4. PUMP AND FILTRATION UNIT.

Type of power	Diameter of suction pipe (inch)	Diameter of delivery pipe (inch)	Max. power	Max. Q (m^3/h)	rpm	Manufactory country	Model
Electrical	8	6	56	150	1470	Germany	NT-125

Pump specifications and filtration unit are illustrated in Table (4). The filtration by sand filter and screen filter and the amount of applied water (Water quantity) under trickle and tape irrigation systems were (3120) m3/fed/season for maize crop.

A. *Some physical prosperities and mechanical analysis of the experimental*

Soil bulk density was determined using the core method according to Black (1965). Table (5) shows the Soil bulk density obtained from the experimentally measured data from the experimental area. Field capacity was determined by the method by Peteres (1965). The permanent wilting point was determined using a pressure membrane according to Stakman and Vander hast (1962). Mechanical analysis of the investigated soil was carried out using standard procedures described by Black (1965). Data in Table (5) illustrates some physical and mechanical properties of soil profile representing the selected area briefly, the soil has clay texture throughout the entire profile.

TABLE 5. SOIL PHYSICAL PROPERTIES AND MECHANICAL ANALYSIS OF THE EXPERIMENTAL.

Soil Depth (Cm)	Particle size distribution			Soil Texture	Bulk Density Mg/m³	Field capacity, %	Wilting point, %	Available water, %
	Sand, %	Silt, %	Clay, %					
0-20	11.4	30.2	58.4	Clay	1.1	38.8	18.4	20.4
20-40	12.1	31.2	56.7		1.2	37.4	17.2	19.2
40-60	12.4	30.5	57.1		1.24	36.6	16.8	19.8

B. Moisture content and its distribution

The soil moisture content and its distribution were measured after irrigation directly (after two hours) at the root zone using the soil moisture unit equipped with three watermarks sensors to measure the soil water tension. Samples were taken at three points at 15 cm from the along each lateral line in the horizontal and vertical directions and below the emitter point throughout the root zone at depths of $0-20$, $20-40$ and $40-60$ cm after irrigation for all different treatments. Moisture content in each layer at difference distance from emission source was determined according to Liven and Van Rooyen (1979). This is done within the area for each treatment

from GR and T-tape treatments at 0, 15 and 30 cm from the emission point throughout the root zone at depths of $0-20$, $20-40$ and $40-60$ cm after irrigation for different irrigation treatments.

C. Emission Uniformity of irrigation system (EU)

Emission Uniformity (EU) is a measure of the uniformity of emission from all the emission points within an entire trickle irrigation system (GR and T-tape) for field tests:

$$EU = \left[\frac{\bar{q}_n}{q_a}\right] x\ 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Where:
EU: Field test emission uniformity, %.
$\bar{q}_n$: Average rate of the low quarter of the field data emitter flow rate reading, l/h
q_a: Average flow rate of all the emitters checked in the field, l/h.

D. Manufacturer coefficient of variation (CV)

Manufacturer coefficient of variation (CV) is an important factor to consider in the selection of emitter Samples of emitters (6emitters from each lateral line) were selected randomly and tested under fixed operating pressure head (1.0 bar) with trickle irrigation system (GR and T-tape). The manufacturers variation is caused by the non-uniform production from the manufacturer coefficient of variation was calculated from the following equation (ASAE, 1991), -

$$CV = [S/\bar{q}]x100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Where-
S: Standard deviation of emitters flow rate.
$\bar{q}$: Emitters average flow rate, l/h.

E. Distribution of emitters flow rate along the lateral lines

Emitters flow rate (qi) was measured by collecting emitters flow rate in a calibrated cylinder during a limited time (5 min) at 5-meters intervals along the lateral line. If a graduated cylinder has the same amount of water along the lateral line, then the distribution is perfect.

F. Flow rate variation (qvar)

The flow rate variation (q_{var}) is used to describe the uniformity of emitter, orifice and it caused by the hydraulic design and manufacturing variability. The flow rate variation (q_{var}) was calculated from the following equation (Wu, 1992)-

$$q_{var} = \left\{\frac{q_{max} - q_{min}}{q_{max}}\right\} x100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

Where:
q_{max}: Maximum flow rate, l/h.
q_{min}: Minimum flow rate, l/h.

G. Yield (Maize crop)

Maize crop was planted during the summer season of 2021/2022. Seeds were sown in 15th of May, three seeds were sown in each hill, spacing between hills were 50 cm and after twenty-one days the seedling were thinned to one plant per hill. It was harvested after (120) days. Nitrogen fertilizers were injected into irrigation water along the growing season according to the recommended doses mentioned by the Ministry of Agriculture, Egypt. Fertilizers were 25.2 kg/fed chicken dung, 50.4 kg/fed (Urea with 46% N), 63 kg/fed k2O, 75.6 kg/fed P2O5 and 126 kg/fed N were injected through subsurface drip irrigation system.

H. Water productivity

Water productivity was calculated according to the following equation (Howell, 2003 and Amer et. al. 2017):

$$\text{Water productivity} = \frac{\text{Crop yield kg/fed}}{\text{Water applied m}^3\text{/fed}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (5)$$

III. RESULTS AND DISCUSSION

The objectives of this research were to study the effect of using two types of trickle irrigation systems (GR and T-tape) on the productivity of the maize crop kg/fed., through studying the moisture distribution, Emission uniformity%, flow rate variation l/h, water applied m3/fed and water productivity kg/m3 to help the farmers in selecting the proper irrigation system and its equipment and to guide them for managing their systems.

A. Soil moisture content and its distribution

The variation in the wetted area, which represented moisture content values were attributed to factors related to the flow rate of emitters from GR treatments and along the T-tape treatments from results experiment and when comparing soil moisture content of GR treatments versus T-tape treatments directly. The results declared that the average of moisture content percentage (GR treatments) ranged from 8.75 to 30.87 % with GR0 and ranged from 15.23 to 34.24

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TABLE 6. SOIL MOISTURE CONTENT (%) IN THE SOIL FOR GR TREATMENTS UNDER FIELD CONDITIONS.

Treatments	Depth of the soil (cm)	Distance from emitters, cm					
		Along the lateral			Across the lateral		
		30	15	0	15	30	45
GR_0	0-20	18.87	19.50	28.13	21.12	20.50	19.62
	20-40	25.25	28.00	30.87	27.25	16.12	9.62
	40-60	13.50	16.25	24.50	15.75	12.50	8.75
GR_{10}	0-20	18.20	19.00	27.53	19.24	19.00	18.52
	20-40	24.6	31.00	32.90	22.52	18.54	12.64
	40-60	20.1	28.62	30.25	23.12	17.64	11.61
GR_{20}	0-20	16.54	17.32	24.52	17.10	16.10	15.23
	20-40	18.72	19.2	33.24	19.62	17.85	16.85
	40-60	23.64	24.8	34.24	23.75	20.62	17.68
GR_{30}	0-20	15.47	17.35	22.65	17.20	16.20	14.62
	20-40	18.20	20.34	36.4	20.98	19.60	17.65
	40-60	24.65	26.53	37.9	27.30	24.1	18.64

% with GR10 and ranged from 11.61 to 32.90 % with GR20 and ranged from 14.62 to 36.4% with GR30 and of the investigated area, this according to situation of taking soil samples in three directions from the source of emitter orifice which showed that the highest moisture content percentage in all GR treatments, will be below emitters directly, and between lateral lines, and getting less away from emitters orifice source as shown at Table 6 and Figs. (1 to 4).

Regarding the effect of irrigation system at soil moisture content to add the same amount of irrigation water for the same area, it can be concluded that, be using all treatments (under GR treatments), it gave high moisture content percentage under the emitters directly in all different soil profiles after irrigation directly comparing with all treatments across or along the laterals which give less values for moisture content.

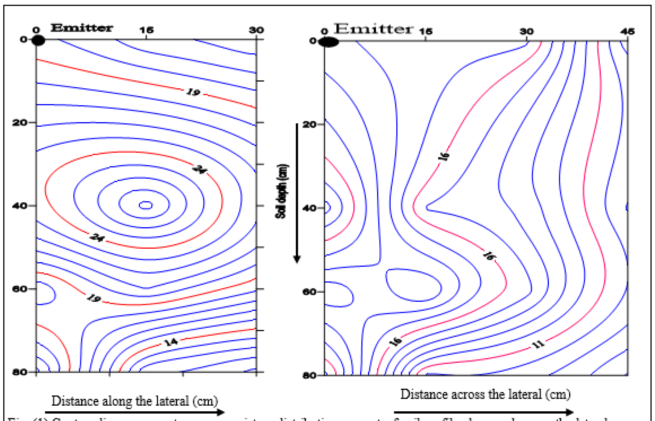

Fig. (1) Contour lines represent average moisture distribution percent of soil profile along and across the lateral line for treatment (GR_0).

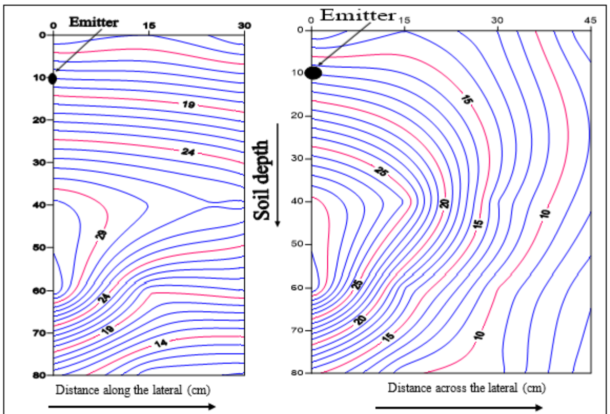

Fig. (2) Contour lines represent average moisture distribution percent of soil profile along and across the lateral line for treatment (GR_{10}).

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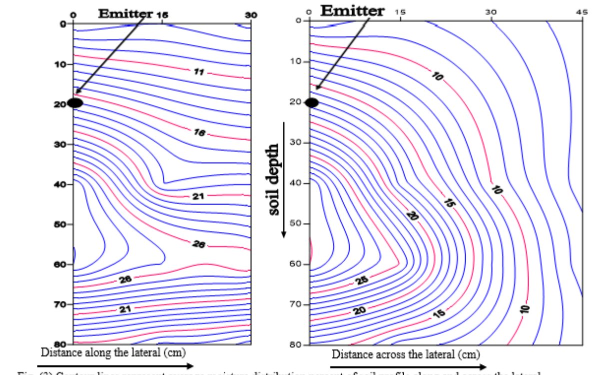

Fig. (3) Contour lines represent average moisture distribution percent of soil profile along and across the lateral line for treatment (GR_{20}).

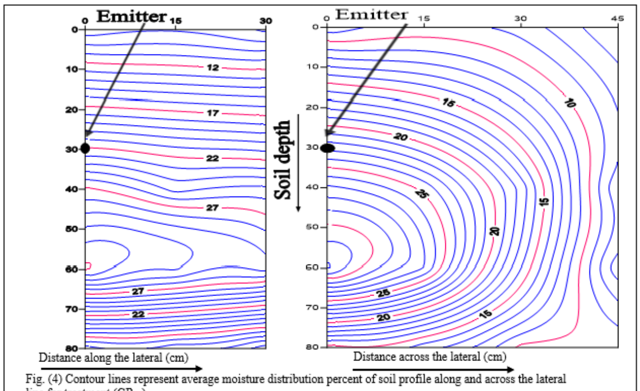

Fig. (4) Contour lines represent average moisture distribution percent of soil profile along and across the lateral line for treatment (GR_{30}).

While the average moisture content percentage (T-tape treatments) ranged from 16.42to 31.78% with TP0 and ranged from 15.64 to 33.78% with TP10 and ranged from 13.64 to 34.72% with TP20 and ranged from 12.64 to 5.81% with TP30 of the investigated area, this is according to the situation of taking soil samples in three directions along one meter of lateral line which showed that the highest moisture content percentage in all treatments (T-tape treatments) will be below along of tape directly, and between lateral lines of tape, and getting less as far as from lateral lines of tape, as shown at Table (7), Figs. (5 to 8).

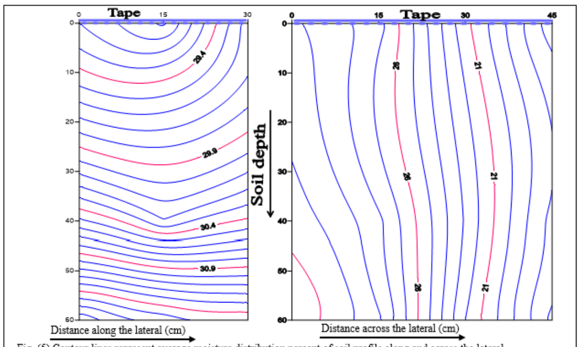

Fig. (5) Contour lines represent average moisture distribution percent of soil profile along and across the lateral line for treatment (TP_{0}).

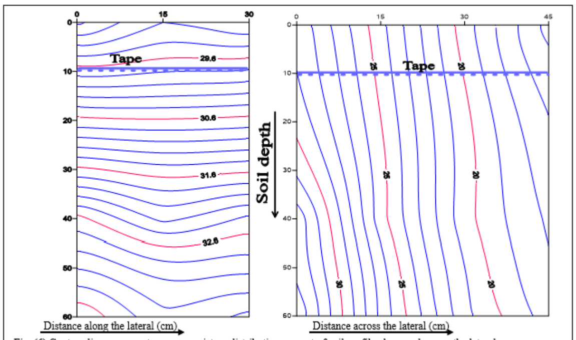

Fig. (6) Contour lines represent average moisture distribution percent of soil profile along and across the lateral line for treatment (GR_{10}).

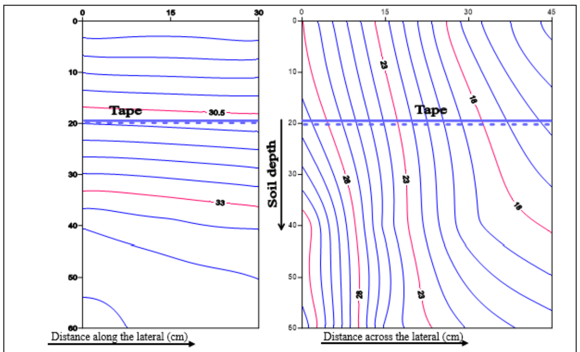

Fig. (7) Contour lines represent average moisture distribution percent of soil profile along and across the lateral line for treatment (TP_{30}).

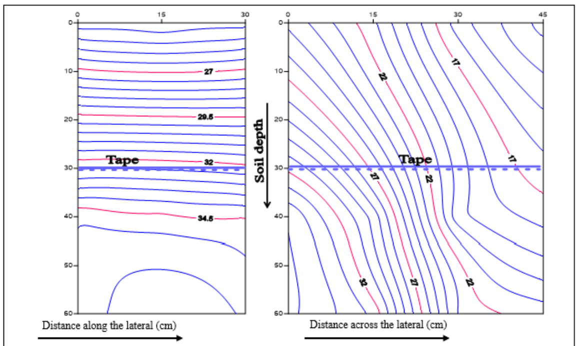

Fig. (8) Contour lines represent average moisture distribution percent of soil profile along and across the lateral line for treatment (GR_{30}).

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TABLE 7. SOIL MOISTURE CONTENT (%) IN THE SOIL FOR TP TREATMENTS UNDER FIELD CONDITIONS.

Treatments	Depth of the soil (cm)	Across the lateral			Along the lateral		
		30	15	0	15	30	45
TP_0	0-20	29.65	28.98	29.20	27.40	21.30	16.42
	20-40	30.42	30.21	30.52	28.24	22.87	17.68
	40-60	31.48	31.56	31.78	29.21	21.98	16.78
TP_{10}	0-20	29.01	29.20	28.75	24.23	19.45	15.64
	20-40	32.45	32.14	32.67	25.42	20.41	17.85
	40-60	33.45	33.24	33.78	26.75	21.32	18.54
TP_{20}	0-20	28.01	28.20	28.05	22.23	16.45	13.64
	20-40	33.45	33.64	33.97	24.62	19.31	17.85
	40-60	34.43	34.21	34.72	24.73	21.92	20.54
TP_{30}	0-20	24.81	24.60	24.75	21.23	15.45	12.64
	20-40	34.47	34.61	34.90	29.62	19.33	17.86
	40-60	35.43	35.81	35.21	32.73	22.92	21.59

Regarding the effect of type irrigation system for the same amount of irrigation water for different area at moisture content percentage in soil profiles, it can be concluded that, it gave high moisture content percentage for all different soil profiles after irrigation directly for T-tape treatments and when the same amount of irrigation water was applied for GR treatments gave low moisture content percentage in all different soil profiles after irrigation directly. It can be conclusion that, T-tape treatments have a more emission uniformity than GR treatments because of the discharge on the one meter is greater than GR treatments.

Regarding the effect of irrigation system at soil moisture content to add the same amount of irrigation water for the same area, it can be concluded that, by using all T-tape treatments, it's gave nearly the same moisture content percentage under the tape directly in all different soil profiles after irrigation directly comparing to all treatments across or along the laterals which give also nearly the same values for moisture content.

A. Distribution of emitters discharge (flow rate) along the lateral lines in the field

Data in figures (9 to 12) showed that, the flow rate variation between the beginning of season was higher than the end of season under GR0 treatment and it follows that the higher distribution of emitters discharges along the lateral lines in the at the beginning of season than resents in the end of season, In the same time data showed that, the flow rate variation between the beginning of season and the end of season was higher under GR0 treatment than TP0 treatment so, the distribution of emitter's discharges along the lateral lines in the testament GR0was less compared with TP0treatment at the beginning and end of season. On the other hand, the data showed that this distribution is not strongly affected under treatment TP0withinthe beginning of season or within the end of season.

B. Flow rate variation

Data in table (8 and 9) showed that, at the beginning of season in the field, the flow rate variation (%) between the first and the end of three lateral lines with

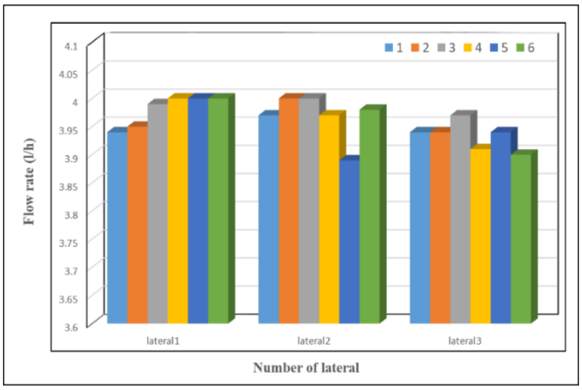

Fig. (9) Flow rate (l/h) under three laterals with 6 emitters on lateral under GR_0 in the beginning of season.

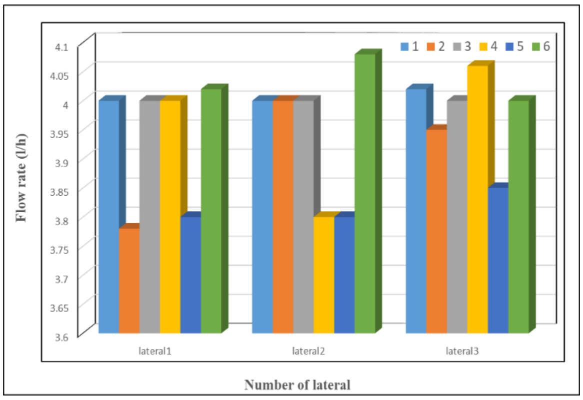

Fig. (10) Flow rate (l/h) under three laterals with 6 emitters on lateral under (GR_0) in the end of season.

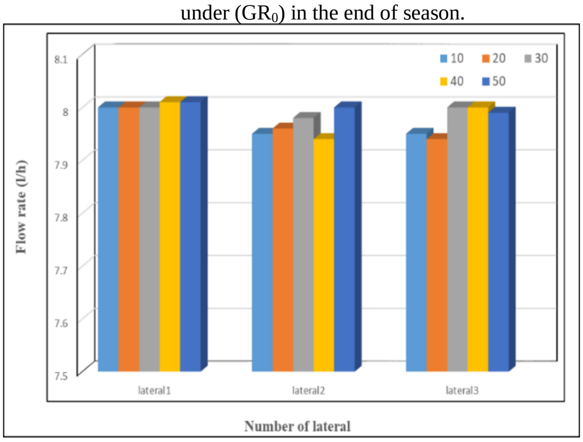

Fig. (11) Flow rate (l/h) every 10 meter along the lateral under (TP_0) at the beginning of season.

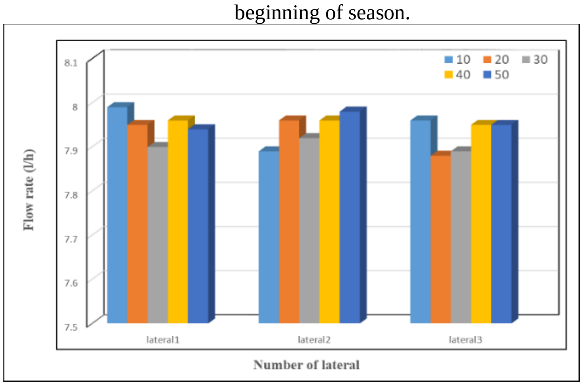

Fig. (12) Flow rate (l/h) every 10 meter along the lateral under (TP_0) at the end of season.

TABLE 8. THE FLOW RATE VARIATION (%) BETWEEN THE FIRST AND THE END OF THREE LATERAL LINES FOR GR0 AND TP0 TREATMENTS IN THE BEGINNING OF SEASON.

Treatments	**Lateral (1)**			**Lateral (2)**			**Lateral (3)**		
	First	Last	VAR (%)	First	Last	VAR (%)	First	Last	VAR (%)
GR_0	4.10	3.98	2.93	3.90	3.80	2.56	4.00	3.89	2.75
TP_0	7.97	7.84	1.63	8.00	7.93	0.88	8.00	7.95	0.62

TABLE 9. THE FLOW RATE VARIATION (%) BETWEEN THE FIRST AND THE END OF THREE LATERAL LINES FOR GR0 AND TP0 TREATMENTS AT THE END OF SEASON.

Treatments	Lateral (1)			Lateral (2)			Lateral (3)		
	First	Last	**VAR (%)**	First	Last	**VAR (%)**	First	Last	**VAR (%)**
GR_0	3.90	3.70	**5.13**	3.90	3.60	**7.69**	3.94	3.70	**6.09**
TP_0	7.92	7.78	**1.77**	8.00	7.90	**1.25**	7.92	7.80	**1.52**

treatment GR0were (2.93%, 2.56% and 2.75%) and the average flow rate variation (%) over all the lateral lines was 2.75%, while at the end of season in the field, the flow rate variation (%) between the first and the end of the same three lateral lines were (5.13%, 7.69% and 6.09%) and the average flow rate variation (%) over all the lateral lines was 6.30% under the same treatment GR0.

On the other hand, at the beginning of season in the field, the flow rate variation (%) between the first and the end of three lateral lines with treatment TP0 were (1.63%, 1.25% and 0.62%) and the average flow rate variation (%) over all the lateral lines was 1.17%, while at the end of season in the field, the flow rate variation (%) between the first and the end of the same three lateral lines were (1.77%, 1.25% and 1.52%) and the average flow rate variation (%) over all the lateral lines was 1.51% under the same treatment TP0.

This means that, the flow rate variation increased from the beginning of season to the end of season by 2.2%, 5.13% and 3.34% under treatment GR0 compared with treatment TP0 which increased by a less ratio0.14%, 0.37% and 0.9%, and it means also that, the flow rate variation increased between treatments $GR_0$and TP_0 from the beginning of season to the end of season the high variation inside treatment GR_0betweenthe beginning and the end of season attributed to variations between flow emitters on the laterals due to its clogging due to cumulative sediments during the season in contrast to the treatment TP_0.

C. Manufacturer coefficient of variation (CV)

Data in figure (13) showed that, at the beginning of season in the field, the manufacturer coefficient of variation (CV) under treatment GR0was (2.36%) while at the end of season in the field, the manufacturer coefficient of variation (CV) was 4.71%.

On the other hand, at the beginning of season in the field, manufacturer coefficient of variation (CV) under treatment TP0 was 0.61% while at the end of season in the field, was 0.87%.

This means that, the manufacturer coefficient of variation (CV) increased from the beginning of season to the end of season by 49.89% under treatment GR0 compared with treatment TP0 which increased by a less ratio 29.88% and it also means that, the manufacturer coefficient of variation (CV) increased between treatments GR0and TP0 from the beginning of season to the end of season. the high variation inside treatment GR0

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between the beginning and the end of season attributed to variations between flow emitters (GR0) due to its clogging (due to cumulative sediments) during season and the clogging along the lateral of tape (TP0) is not high.

D. Water uniformity in the field (Emission uniformity) % (EU)

A system designed for more uniform water application, may be considered as more efficient. In trickle irrigation (GR), water is carried in a pipe network to the point where it infiltrates into the soil. Therefore, the uniformity of application depends on the uniformity of emitter discharge throughout the system but in trickle irrigation (T-tape), water is carried in a pipe network to the more of points where it infiltrates into the soil. Therefore, the uniformity of application depends on the uniformity of T-tape discharge throughout the system.

Data in figure (14) showed that, at the beginning of season in the field, the emission uniformity (EU) under treatment GR0 was 96.1% while at the end of season in the field, the emission uniformity (EU) was 92.1%. On the other hand, at the beginning of season in the field, emission uniformity (EU %) under treatment TP0 was 99% while at the end of season in the field was 98.8%.

Emission uniformity (EU) increased from the beginning of season to the end of season by 4.2% under treatment GR0 compared with treatment TP_0 which increased by a less ratio **0.19**% and it also means that, the emission uniformity (EU) increased between treatments GR_0 and TP_0 from the beginning of season to the end of season. the high variation inside treatment GR_0 between the beginning and the end of season attributed to variations between flow emitters (GR_0) due to its clogging (due to cumulative sediments) during season and the clogging along the lateral of tape (TP_0) is not high.

E. Crop yield

Figure (15) showed that the highest yield was obtained in the treatment GR0 (3120 kg/fed) than treatments GR10, GR20 and GR30 since the yields were (3000 kg/fed, 2650 kg/fed and 2312 kg/fed respectively, meanwhile Figure (16) showed that the highest yield was obtained in the treatment TP20 (3643 kg/fed) than treatments TP10, TP0 and TP30since the yields were 3520 kg/fed, 3325 kg/fed and 3100 kg/fed respectively, using the same amount of irrigation water 3120 m3/fed for all treatments.

On the other hand, figure (17) showed that the yield in the treatments TP0, TP10, TP20 and TP30 were higher than treatments GR0, GR10, GR20 and GR30 by a ratio 6.17 %, 14.77 %, 37.43% and 25.41 % respectively. The highest yield under all treatments TP compared with GR could be attributed to the high moisture distribution and high uniform distribution of sufficient available water and the decreasing in the variation of discharge along and between the lateral lines in the network.

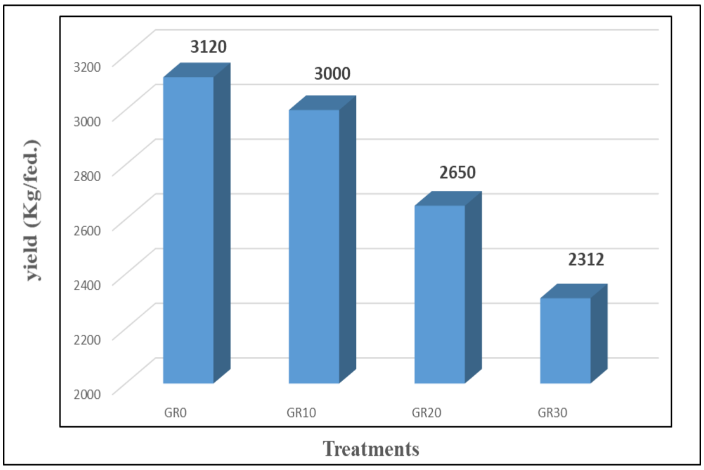

Fig. (15). Yield productivity (kg/fed) under GR treatments.

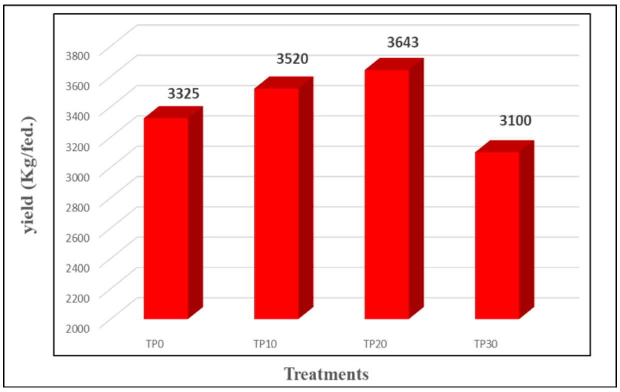

Fig. (16). Yield productivity (kg/fed.) under T-tape treatments.

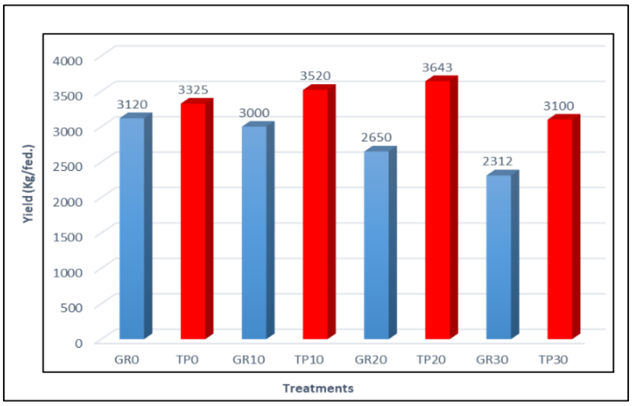

Fig. (17). Yield productivity (kg/fed.) under GR treatments and T-tape treatments.

F. Water productivity

Figure (18) showed that the highest water productivity was obtained in the treatments GR0 (1.00 kg/m³) than treatments GR10, GR20 and GR30 since the water productivity were 0.96 kg/m³, 0.85 kg/m³ and 0.74 kg/m³ respectively, meanwhile Figure (19) showed that the highest water productivity was obtained in the treatment TP20 were 1.17kg/m³ than treatments TP10, TP0 and TP30 since the water productivity were 1.13 kg/m³, 1.07 kg/m³ and 0.99 kg/m³ respectively.

On the other hand, figure (20) showed that the water productivity in the treatments TP0, TP10, TP20 and TP30 were higher than treatments GR0, GR10, GR20 and GR30 by a ratio 6.54%, 15.1%, 27.35% and 25.25% respectively.

The highest water productivity under all treatments TP compared with GR due to the variation in the yield with using the same amount of irrigation water 3120 m3/fed for all treatments.

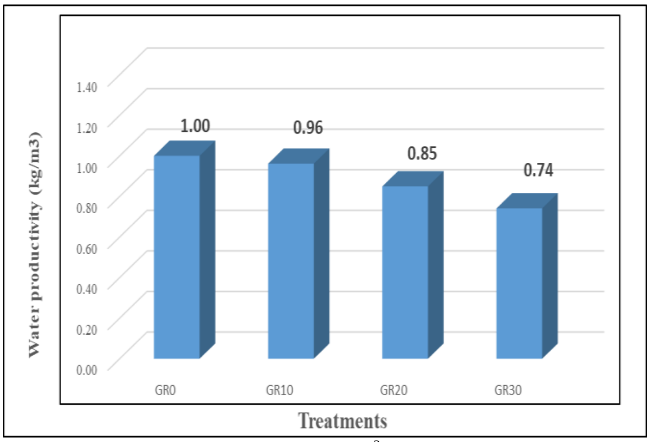

Fig. (18). Water productivity (kg/m^3) under GR treatments.

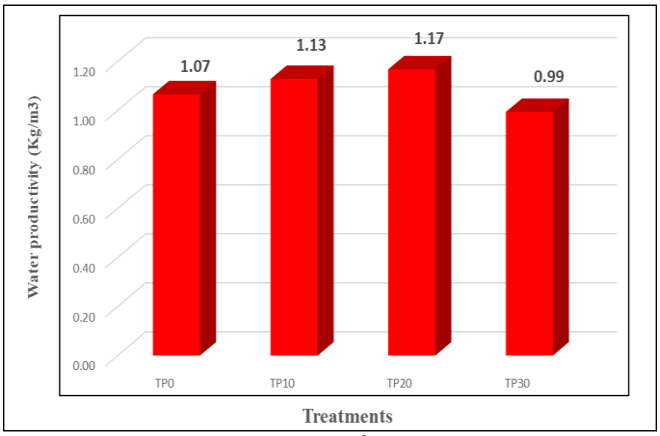

Fig. (19). Water productivity (kg/m^3) under T-tape treatments.

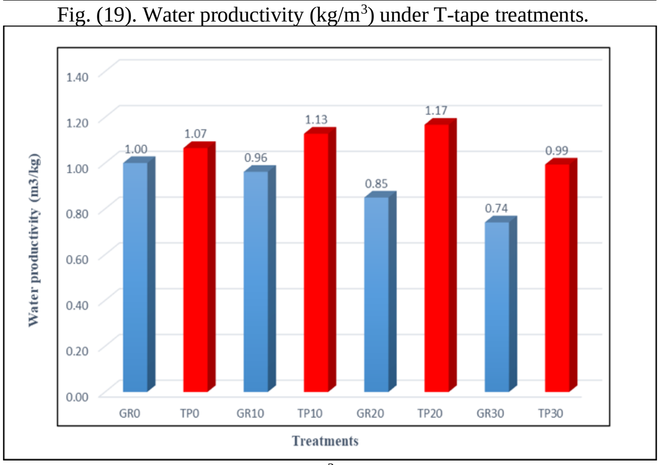

Fig. (20) Water productivity (kg/m^3) under GR treatments and T-tape treatments.

IV. CONCLUSION

1- The old lands of clay soil could be using the T-tape irrigation system instead of GR irrigation system because of many advantages, including that the highest emission uniformity and distribution uniformity up to 99% and the lowest the manufacturer coefficient of variation (CV) which was 0.61%.

2- Using T-tape irrigation system (special with T-tape under depth of soil 10 cm and 20 cm) led to an increase in agricultural productivity for maize crop and thus water productivity with the same amount of water applied which applied in GR irrigation system.

3- Using T-tape irrigation system, it's gave nearly the same moisture content percentage under the tape directly in all different soil profiles after irrigation directly comparing with all treatments across or along the laterals which give also nearly the same values for moisture content. while under GR irrigation system it's gave high moisture content percentage under the emitters directly in all different soil profiles after irrigation directly comparing with all treatments across or along the laterals which give less values for moisture content, which led to more emission uniformity and distribution uniformity and less manufacturer coefficient of variation (CV) under T-tape irrigation system.

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