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Effect of pipe type and Emitters discharge on performance criteria of surface drip irrigation system

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Abstract. A field experiment was conducted in Jazeerah Al- Ramadi / Al-Hamidiyah research station (latitude33^o 27^’ 〖 11.9〗 ^(”)N , longitude 43^o 23^’ 025^(”) E (duration 2020. This study was conducted to investigate the effect of pipe types and emitters discharge on performance criteria of surface drip irrigation system. Therefore, a two factorial experiment was set as randomized complete block design with three replications. The first factor included the type of pipes and emitters, namely Turbo, GR and T-Tape. While the second factor involved the emitters discharge which consist of two levels i.e., 4 (D4) and 8 (D8) $L.h^{-1}$. The irrigation system was initially evaluated in the field before planting by testing three operating pressures (50 ,100 and 150 Kpa) to determine the actual discharge of the emitters closed to their design discharge (4 and 8 $L.h^{-1}$) for each emitter to calculate the manufacturing coefficient of variation (CV), distribution uniformity and the discharge variation ratio at each operating pressure. Results showed that the best discharge (Closed to design discharge of 4 $L.h^{-1}$) was obtained at the 50 Kpa operating pressure which gave 3.99,3.90 and 3.81 $L.h^{-1}$ when using the T-Tape pipe and GR and Turbo emitter compare when the discharge of 8$L.h^{-1}$ has been used which gave 7.96, 7.84 and 7.59 $L.h^{-1}$ when the former pipe and emitters were used. The best coefficient of variation was observed when the T-Tape pipe and GR and Turbo emitter were used with discharge of 4 $L.h^{-1}$ up to 0.1300, 0.2200 and 0.2600 compare to 0.1300, 0.2700 and 0.3500 when the same former pipe and emitters were used with discharge of 8L. h^{-1}. Similarly, the best distribution uniformity was obtained when the T-Tape pipe and GR and Turbo emitter has been used with discharge of 4 $L.h^{-1}$ which gave 94.68, 91.74 and 90%. Likewise, the most acceptable variety discharge ratio was observed when the same prior pipe and emitters were used with discharge of 4 $L.h^{-1}$ by giving 7.23 ,11.90 and 12.19 %.

1. Introduction

Unsustainable water use is a problem across the globe. Therefore, rationalizing use of water resources, applying modern irrigation schemes, improving its performance, and reducing losses will increase water use efficiency. Consequently, saving considerable amount of water. The concept of the drip irrigation system is based on delivering water to the plant through a network of valves, pipes, tubing, and emitters in the form of continuous and separate drops during short periods of time according to plant water requirements. The emitters dissipate the delivered water pressure; Therefore, these emitters are called regulators. Despite the recent advances in industrial technology nevertheless, there are difficulties in producing completely symmetric emitters due to their small diameters and thin long internal paths, which causes a difference in their internal shape from one emitter to another. Accordingly, causes the variety of the distribution of the supplied water to the field, which is called the coefficient of manufacturing variation of the emitters, which is one of the most crucial factors affecting the homogeneity and regularity of the drip irrigation system, which directly affects the system efficiency [1], [11] indicated that the efficiency of the drip irrigation system is affected by the coefficient of manufacturing variation, which in turn affects the variation of discharge compared to hydraulic losses such as friction losses. Results under field condition reported by [12] showed that the acceptable coefficient of manufacturing variation ranges from 3% to 20% and when exceeds 20%. However, when the coefficient of manufacturing variation greater than 20 % is considered to be poor. Previous studies show the importance of distribution uniformity in the irrigation system and the adverse effects results from not uniform distribution [10]. Study conducted by [13] showed that the fundamental reason for the irregular distribution is the coefficient of manufacturing variation due to hydraulic differences caused by industrial deformity when manufacturing these emitters. Some points related to the manufacture of emitters must be taken into account, namely having a lower flow rate of water (0.5 to 8 L.h-1), high ability to resist clogging and low production cost [8]. In drip irrigation system, high uniformity is required to minimize the water irrigation losses as well as different emitters in its tolerance of pressure [6]. The aim of this study was to determine the effect of pipe types and drip emitters discharge on evaluating performance criteria of surface drip irrigation system.

2. Materials and Methods

A field experiment was conducted in Jazeerah Al- Ramadi / Al-Hamidiyah research station (latitude$33^{o}\ 27^{'}\ 11.9^{''}$N , longitude $43^{o}\ 23^{'}\ 025^{''}$E) duration 2020.In this study the following factors were considers:

1- Types of Drip Tubing, namely:
A- Conventional polyethylene pipes with a diameter of 16 mm, provided with turbo-type emitters (TR).
B- Polyethylene pipes with a diameter of 16 mm, with inline GR type emitters.
C- Flat pipes with a diameter of 16 mm, with inline T-Tape emitters.
2- Emitters Discharge(D)
A- Emitters with discharge of 4L.h^{-1} (D_4).
B- Emitters with discharge of 8L.h^{-1}(D_8).

2.1. Experimental Design and Evaluation of the Drip Irrigation System

A two factorial experiment was set as randomized complete block design (RCBD) with three replications. The first factor included the type of pipes and emitters, namely Turbo, GR and T-Tape. While the second factor involved the emitters discharge which consist of two levels i.e., 4 (D4) and 8 (D8) L.h-1. The irrigation system was initially evaluated in the field before planting to choose the best operating pressure to be adopted throughout and after the experiment to compare the performance and efficiency of the irrigation system as the following:

1- Actual Emitters Discharge Measurement (ED)

Three operating pressures were selected i.e., 50, 100 and 150 kPa. The pressure was controlled by regulated the engine rotational speed per minute (rpm). The desired pressure was read on the pressure gauge fixed at the beginning of the field at the network connection of the main pipe, secondary pipe and Back water return pipe to the pool.

The emitters discharge was measured according to their design discharge 4 and 8 L.h^{-1} at each side pipe individually using the volumetric method at fixed interval time (15 minutes). The received volume of water was measured measured using a 2000 ml cylinder, the measurement process was repeated three times at each operating pressure at each discharge. the actual discharge values near to the design discharge at the emitter discharge of 4L.h^{-1} was attained from the operating pressure of 50 kPa (0.5 bar), by giving 3.99, 3.90 and 3.81 L.h^{-1} when the T-Tape type pipes and emitters GR and Turbo has been used respectively. While the actual discharges near to the design emitter discharge of

8L.h^{-1} at the same operating pressure (50 kPa) were 7.96, 7.84 and 7. 54L.h^{-1} for the same pipes and emitters previous mentioned.

Actual discharge was calculated according to equation mentioned by [5] as the following:

$$Q = \frac{V}{t} \qquad (1)$$

Q is emitter actual discharge (L.h^{-1})
V is the received water volume (L).
t is the operation time (hour).

2- Calculation of Manufacturing Variation Coefficient (CV)

Manufacturing variation coefficient was calculated based on statistical analysis of the data obtained from five selected emitters from each pipe, according to the guide published by [4]. According to statistical analysis the standard deviation for all emitters was calculated using the following statistical formula:

$$CV = \frac{S}{X} \qquad (2)$$

Where:

CV is Manufacturing variation coefficient.
X is general average discharge (L.h^{-1}).
S is standard deviation of discharge (L.h^{-1}). The standard deviation of discharge was calculated according to the following statistical formula:

$$S = [\frac{\sum_{i=1}^{n}(xi-x)^2}{n-1}]^{0.5} \qquad (3)$$

Where:
xi is emitter actual discharge (L.h^{-1}),
n is the number of selected emitters.

3- Calculation of Distribution Uniformity (DU)

Distribution uniformity was calculated according to the equation mentioned by [12].

$$EU = 100[1.0 - \left(\frac{1.27}{\sqrt{2}} * CV\right)\frac{qm}{qa}] \qquad (4)$$

Where:
EU is the distribution uniformity (%).
CV is manufacturing variation coefficient.
qm is the average low-quarter emitter discharge (L.h^{-1}).
qa is the average of discharge (L.h^{-1}).
n is the number of emitters per plant.

4- Calculation of Emitter Flow Variation

The emitter flow variation resulted from manufacturing variation coefficient was calculated according to the following equation:

$$q_{var}=[1-\frac{q_{min}}{q_{max}}] \qquad (5)$$

Where:
q_{var} is the emitter flow variation (%).
q_{max} is the maximum emitter flow (L.h^{-1}).
q_{min} is the minimum emitter flow (L.h^{-1}).

3. Results and Discussion

3.1.Manufacturing Variation Coefficient Before and After Planting

The delete results listed in Table 1 ***A*** shows the effect of type of pipes, emitters and discharges on the values of the manufacturing coefficient of variation before planting, where the results showed that the manufacturing coefficient of variation were significantly increased, according to the types of pipes and emitters used in the study, where the values were 0.1300, 0.2200 and 0.2600, when the T-Tape type GR and Turbo emitters has been used, with operating pressure of 50 kPa and a discharge of 4L.h^{-1}respectevly. Meanwhile, when the discharge of 8L.h^{-1} was used, the results of the manufacturing coefficient of variation were 0.1300, 0.2700 and 0.3500 for T-Tape pipes and GR and Turbo type emitters respectively. The evidence showed that the manufacturing coefficient of variation observed in this study for the discharge of 4 and 8 L.h^{-1} were typical of those classified by the American Society of Agricultural Engineers [3] for the T-Tape pipe, which indicated that when the value of the manufacturing coefficient of variation ranges between 0.10 > CV > 0.20 classified as medium. on contrary, the values were inconsistent to each of the GR and Turbo type emitters (point-source emitters), probably due to the fact that no two symmetric emitters could be manufactured, unless there was a difference in the values of the manufacturing coefficient of variation, this is consistent with [8]. While Table.1 ***B*** shows the effect of type of pipes, emitters and discharges on the values of the manufacturing coefficient of variation after planting, the results according to the values of the least significant difference at the level of 0.05 showed significant increases of coefficient of variation reached 0.1400, 0.2700 and 0.3000 with an average of 0.2367 for T-Tape, GR and Turbo emitters respectively, when the discharge of 4L.h^{-1} was adopted. While the coefficient of variation values was increased when the discharge of 8L.h^{-1} was used by giving 0.1500, 0.3200 and 0.4000 with an average of 0.2900 when the same aforementioned pipe and emitters were used respectively. The percentages of increase when comparing the values of manufacturing coefficient of variation before and after planting under 4L.h^{-1} were 7.69%, 22.73% and 15.38% for the T-Tape and GR and Turbo emitters respectively. While the percentage increase in manufacturing coefficient of variation before and after planting was in the following trend 15.38%, 18.52% and 14.28% for the same mentioned pipes and emitters, when the discharge of 8L. h^{-1} has been used. Therefore, the evidence show that the classification of the line source emitters was within the permissible limits, while the classification of the GR and Turbo type emitters was out of permissible limits for the point-source emitters, as indicated by [3], the increase in the values of the coefficient of variation probably due to the accumulation of some deposits in the pipes and emitters accordingly occurrence of clogging in the transmission and distribution network of the drip irrigation system used in the study, and this is consistent with [7] who reported an increase in the values of manufacturing coefficient of variation after a period of time from the start of operation. Therefore, his study recommended carrying out maintenance and installing filters to protect and preserve a drip irrigation system.

The statistical analysis did not show significant interaction in terms of manufacturing coefficient of variation between the types of pipes and emitters discharges of irrigation system before planting, while significant interaction between the study factors was observed after planting, possibly due to the positive effect of the study factors, namely pipes types and emitters discharges which gave a positive effect in one direction.

Table 1. Effect of pipe type and emitters discharges on the values of the manufacturing coefficient of variation.

		A-Types of pipes and emitters		
Discharge(L.h^{-1})	Turbo	GR	T-Tape	Average
4	0.26	0.22	0.13	**0.2033**
8	0.35	0.27	0.13	**0.25**
Avarage	**0.305**	**0.245**	**0.13**	
L.S.D(0.05)	Discharge	For pipes and emitters	Discharge*pipes and emitters	
	0.3349	**0.04102**	**0.05801**	
		B-Types of pipes and emitters		
Discharge(L.h^{-1})	Turbo	GR	T-Tape	Average
4	0.3	0.27	0.14	**0.2367**
8	0.4	0.32	0.15	**0.29**
Average	0.35	0.295	0.145	
L.S.D(0.05)	Discharge	For pipes and emitters	Discharge*pipes and emitters	
	0.02692	**0.03297**	**0.04662**	

Note: ***A*** indicates the manufacturing variation coefficient values before planting. ***B*** indicates the manufacturing variation coefficient values after planting.

3.2. Distribution Uniformity Before and After Planting

Table 2 ***A*** shows the effect of the type of pipes, emitters and its discharges on the distribution uniformity values before planting, it is noticed that there was a significant decrease in the values due to the effect of the treatments under study (pipes, emitters and discharges), where the uniformity values reached 94.68%, 91.74% and 90.00%, with an average of 92.14%, when adopting T-Tape pipes, GR and Turbo emitters with a design discharge of 4 L.h^{-1}, while the uniformity values were 94.68%, 90.29% and 87.03% with an average of 90.67% when adopting emitters with a design discharge of 8L.h^{-1} for the same aforementioned pipes and emitters, the results is consistent with [2] which states that uniformity is classified as excellent if the values are 90% or more, also the results consistent with [10].

Table 2***B*** shows that the distribution uniformity values were affected by the study factors according to the evaluation conducted for the system at the end of the study (after planting). It is clear from the table that the obtained uniformity values slightly decreased compare to before planting, based on the values of the least significant difference (L.S.D) at the level of 0.05, where the values at the emitters design discharge of 4 L.h^{-1} were 89.55%, 87.50% and 84.20% with an average of 87.08% for T-Tape, GR and Turbo type emitters respectively. While using emitters with a design discharge of 8L.h^{-1}, the uniformity values were 90.00%, 86.15% and 83.10% when the same former type of pipes and emitters used with an average of 86.52%. Comparing the data at the end of the experiment with those data prior to planting, the percentages of decrease in the uniformity values amounted to 5.73%, 4.85% and 6.88% when emitters with design discharge of 4 L.h^{-1} were used for the T-Tape, GR and Turbo type emitters respectively. While the percentages of decrease reached 5.20%, 4.81% and 4.73% when emitters with a design discharge of 8 L.h^{-1} were used for the same previously mentioned pipes and emitters respectively.

The reduction in the uniformity values due to the rise in the values of the manufacturing coefficient of variation, where it is one of the main reasons for the difference in the homogeneous distribution (uniformity) of water in the drip irrigation system, this occurs due to the difference in hydraulic properties resulting from the manufacturing tolerances during manufacturing emitters, in addition to the final manufacturing process, the results are consistent with [13]. The statistical analysis according to the L.S.D values at 0.05 level did not show significant interaction between the study factors (type of pipes, emitters and its discharge) and its impact on the uniformity values before and after plantin.

Table 2. Effect of pipes type and emitters discharge on distribution uniformity values.

		A-Types of pipes and emitters		
Discharge(L.h^{-1})	Turbo	GR	T-Tape	Average
4	90	91.74	94.68	92.14
8	87.03	90.29	94.68	90.67
Average	88.51	91.01	94.68	
L.S.D(0.05)	Discharge	For pipes and emitters	Discharge*pipes and emitters	
	1.381	**1.692**	**2.393**	
		B-Types of pipes and emitters		
Discharge(L.h^{-1})	Turbo	GR	T-Tape	Average
4	84.2	87.5	89.55	87.08
8	83.1	86.15	90	86.52
Average	83.65	86.83	89.92	
L.S.D(0.05)	Discharge	For pipes and emitters	Discharge*pipes and emitters	
	1.942	**2.379**	**1.942**	

Note: ***A*** indicates the manufacturing variation coefficient values before planting. ***B*** indicates the manufacturing variation coefficient values after planting.

3.3. Discharge Variations Values Before and After Planting

Table 3 ***A*** shows the effect of the type of pipes and emitters and its discharge on the discharge variations values of emitters before planting, where a highly significant increase was noted in the influence of the study factors on the discharge variations where the values reached 7.23%, 11.20 % and 12.19 %, with an average of 10.44 % when using the T-Tape, GR and Turbo type emitters respectively, when emitters with design discharge of 4 L.h^{-1} and operating pressure of 50 kPa. were used. While the values of the discharge variation clearly increased by giving 7.78%, 15.11% and 17.65% with an average of 13.51% when emitters with design discharge of 8 L.h^{-1} and operating pressure of 50 kPa. were used with the same sequence of pipe and emitters previously mentioned. The emitters discharge variation probably due to the difference of the manufacturing coefficient of variation coupled with the distribution uniformity values, where it decreased when adopting emitters with a discharge of 4L, h^{-1}, while increased significantly when the emitters with a discharge of 8 L.h^{-1} under the same operating pressure (50 Kpa) has been used, the results are consistent with [9]. Table 3 ***B*** shows the discharge variations values of emitters have significantly increased due to the influence of the factors under study (type of pipes and emitters discharge) through the adoption of evaluation criteria for drip irrigation systems at the end of the experiment (after planting), where the values increased significantly, compare to before planting, where the values were 9.25%, 14.18% and 16.25% with an average of 13.23% for the type of T-Tape and emitters type GR and Turbo, with discharge of 4 L.h^{-1} respectively. while the discharge variations values were 10.25%, 18.20% and 20.20%, with an average of 16.22% for the emitters discharge of 8L.h^{-1} for the same pipes and emitters previously mentioned respectively. the percentages of increase of the discharge variations values between before and after planting were as the following: 27.94%, 19.16% and 33.31% for 4L.h^{-1} for T-Tape, GR and Turbo type emitters respectively. whereas the percentages of increase in the discharge variations values of the emitters for the discharge 8L.h^{-1} were 31.75%, 25.97% and 14.45% for the same pipes and emitters previously mentioned respectively. The discharge variations values between the beginning of the experiment (before planting) the end (after planting) were differed apparently due to manufacturing tolerances of emitters. Consequently, the evaluation of the drip irrigation system will be based on the test data and not on the manufacturing data supplied by the producing company and the evaluation should be carried out before and after the experiment, this is consistent with [6].

The statistical analysis according to the L.S.D values at 0.05 level did not show significant interaction between the study factors (type of pipes, emitters and its discharge) and its impact on the discharge variations values before and after planting.

Table 3. Effect of pipe type and emitters discharges on discharge variations values.

		A-Types of pipes and emitters		
Discharge ($L.h^{-1}$)	Turbo	GR	T-Tape	Avarage
4	12.19	11.9	7.23	10.44
8	17.65	15.11	7.78	13.51
Average	14.92	13.5	7.5	
L.S.D(0.05)	Discharge	For pipes and emitters	Discharge*pipes and emitters	
	1.705	**2.089**	**2.954**	
		B-Types of pipes and emitters		
Discharge ($L.h^{-1}$)	Turbo	GR	T-Tape	Avarage
4	16.25	14.18	9.25	13.23
8	20.2	18.2	10.25	16.22
Average	18.23	16.19	9.75	
L.S.D(0.05)	Discharge	For pipes and emitters	Discharge*pipes and emitters	
	2.106	**2.579**	**3.648**	

Note: ***A*** indicates the manufacturing variation coefficient values before planting. ***B*** indicates the manufacturing variation coefficient values after planting.

4. Conclusion

According to the data and conditions of this study, the following can be concluded, the possibility of obtaining the best values for the manufacturing coefficient of variation, uniformity of water distribution and discharge variations of emitters, at operating pressure of 50 kPa, by using T-Tape pipes and obtaining an actual discharge of 3.99 $L.h^{-1}$, which is near to the design emitter discharge of 4$L.h^{-1}$. Conducting a field evaluation of the drip irrigation system before starting the study, which includes determining the actual discharge near to the design discharge, as well as the appropriate operating pressure, which gives the best applied criteria for that system, such as manufacturing coefficient of variation, uniformity of water distribution and discharge variations of emitters. Therefore, researcher should not rely on the system specification provided by the manufacturer. Since this study and its technical and hydraulic aspects, considered one of the first studies in Iraq. therefore, it is necessary to adopt the results of this study practically under the field condition and academic fields to face water scarcity and ensure water sustainability in the future.

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