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ARTICLE

ANALYSIS OF EFFECT OF SPRINKLER FUNCTION PRESSURE ON UNIFORMITY OF WATER DISTRIBUTION IN TRICKLE IRRIGATION: CASE STUDY IN TORBAT HEIDARIYEH ZONE

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ABSTRACT

Using of trickle irrigation systems (sprinklers) is one of the efficient solutions in saving and further protection from water supplies. If these systems are properly designed, executed, and managed, they will cause reducing water wastage and improving uniformity of water distribution. Uniformity of water distribution will be possible in trickle irrigation (sprinkler) when the factors, which cause reduction of uniformity, are identified and controlled as possible. In order to analyze effect of pressure of sprinkler function on uniformity of water distribution, several experiments were carried out according to ISO 7749/2 Standard (1990) by single sprinkler technique in a pilot field locating on Torbat Heidariyeh Zone during spring and summer in 2016. The test was implemented at 3 different pressure levels (2.2, 3.5, and 4.7 atmospheres) within the range of suggested pressures by Manufacturing Company. Analysis on results of finding from uniformity of water distribution at different pressure levels signifies that there is significant difference between the studied pressures at level of 5%. The mutual effect of sprinkler type and pressure suggests that following to rise of pressure at any sprinkler, uniformity of water distribution has been increased and water distribution uniformity coefficient has been added by rising pressure (from 2.2 to 4.7 atmospheres) and this relationship was not linear but this gradient was higher at low pressures (2.2-3.5 atmospheres) than high pressures (3.5- 4.7 atmospheres). If pressure level (about 3.5- 4.7 atmospheres) has been selected in the studied sprinkler, uniformity coefficient will be greater than 80%.

KEY WORDS
Sprinkler, Trickle irrigation, Function pressure (stress), Water distribution uniformity coefficient

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INTRODUCTION

Water shortage and limitation of water supplies, particularly in Iran, requires conditions under which water is used at maximum level and in order to prevent from water wastage as possible. Utilization from irrigation systems is assumed as one the basic steps taken in saving and further protection from water supplies in agriculture with potential to achieve high efficiency and uniformity. Uniformity of irrigation means the same quantity of water to be distributed in all points of land. Total uniformity is not practically possible in irrigation because uncontrollable factors play role in this process. Whereas high uniformities are usually accompanies by rise of fixed costs and exploitation and maintenance costs thus the project should be implemented in such a way that in addition to having high uniformity, it should be also economically justifiable. Sprinklers should distribute water more uniformly as possible and without creation of runoff water on ground surface. To this end, various types of sprinklers have been designed and manufactured.

In any case, unsuitable pressure in trickle system (whether high or low) causes some points to be less irrigated on the given land where the effect of this process is visible on growth of plant in those areas. Uniformity of water distribution in trickle irrigation system mainly depends on this point that most appropriate amount of pressure and size of sprinkler to be selected with respect to distance between sprinklers.

Losses of depth penetration are more controllable in trickle irrigation than in surface irrigation and it can be reduced. When the system starts operation in trickle irrigation, irrigation practice begins simultaneously at all points and period of irrigation time is the same at all points. For this reason, losses of depth penetration are lesser than in surface irrigation. In order to explore effect of different quantities of pressure of function, distances, and arrangement of sprinklers on uniformity of water distribution in trickle irrigation, indicated that following to rise of function pressure, Christiansen's uniformity coefficient of water distribution is increased nonlinearly (rise of pressure from 35m to 40m increases further water distribution uniformity coefficient from 40m to 45m compared to rise of operational pressure.

Among the uniformity equations presented by various researchers, Christiansen's equations in Hawaii Sugarcane Association, Hardt and Reynolds depend on field conditions at least level and they can be used in different fields with more confidence. After study on different states and conditions, Christiansen [1] has suggested distances for sprinklers. He has offered ratio of distances between sprinklers with distribution diameters 0.4×0.6 and 0.5 respectively for rectangular and square arrangements.

Effect of wind speed and hydraulic properties on water distribution uniformity on prevalent sprinklers in trickle irrigation have been studied. The results of that survey indicate that there is no linear relationship among pressure and water distribution uniformity in all of tested sprinklers and curve gradient of pressure uniformity coefficient became greater at lower pressures. Uniformity coefficient was increased following to rise of pressure within studied range (all of wind speeds, used sprinklers, and designated intervals). However curve gradient of uniformity coefficient and wind speed is greater at lower pressures (3kg/m3) and this relation has been kept at all wind speeds [3].

MATERIALS AND METHODS

The given tests were carried out according to ISO 7749/2 Standard [4] by means of single sprinkler technique in pilot field locating on Torbat Heidariyeh zone (longitude: 59°, 13´ and 35°, 20´) in spring and summer 2016. Anemometer (or wind gauge) was utilized to measure wind speed. With respect to the given information by manufacturing companies of sprinkler, this experiment was conducted at 3 different levels with the range of suggested pressures by Manufacturing Company. The needed water for this system was supplied from a pond with dimensions of (2.5×25×30) near to the pilot field. Single sprinkler was utilized on blow sprinklers or the current sprinklers used in under-pressure irrigation projects (Weir-35 Sprinkler) implemented with operational range of sprinkler (2.5-4.7 atmospheres) in Torbat Heidariyeh zone. The period of system operation was at least an hour in any experiment. After preparation of land and system implementation, the identical collector vessels with 3×3m2 arrays were arranged before any assessment and water depth irrigation system were collected at any assessment step and accurately measured with graded cylinder at any vessel. The measurable parameters include wind speed, water pressure, discharge and amount of collected water in cans due to water output in this study. Similarly, it was tried these tests to be repeated accurately under similar conditions with respect to change in quantities of atmospheric parameters in respective of time and non-occurrence of the previous conditions. In order to achieve objectives in this study, tests were conducted at six levels of intensity of flowing wind this zone (2, 3, 5, 5, 6, 7, and 11) and in three treatments of sprinkler average pressure (2.2, 3.5, and 4.7 atmospheres).

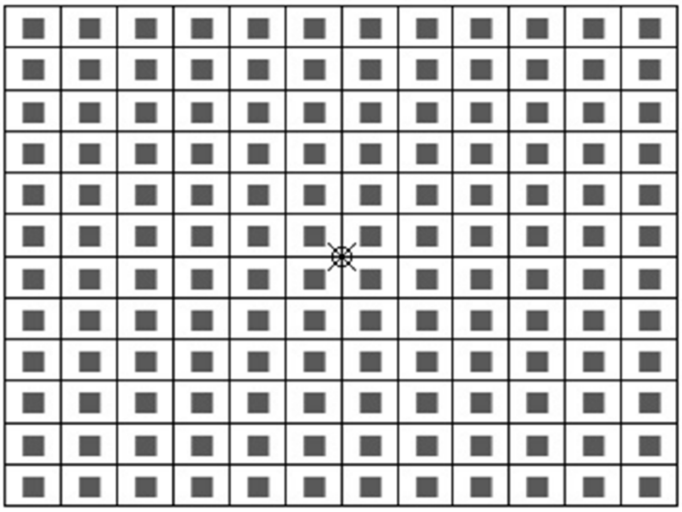

Fig.1: General view of settlement of water collection vessels where these vessels are placed as a grid with dimensions of (3×3m) around Weir-35 sprinkler.

After preparation of ground and system implementation in this study, identical collector vessels were arranged with distances (3×3m2) and square arrays (12×12) before any assessment and after any assessment phase of irrigation system, depth of collected water was accurately measured in any measurement vessel. One hour was designated for period of system operation at any phase of test. Depth of collected water in any measurement vessel was measured accurately after any phase of assessment of irrigation system. Likewise, meteorological parameters were measured by installation of anemometer system in the given zone.

Christiansen’s uniformity coefficient formula was used to compute uniformity coefficient of system.

$$UC = 1 - \sum_{i=1}^{n} \frac{|x_i - \bar{x}|}{n\bar{x}}$$

UC: Christiansen’s uniformity coefficient (decimal)
xi: Depth of water in each of water collection cans (mm)
: Mean depth of water in collection cans (mm)
n: Number of water collection cans
Given that the rate of propagation has been measured around a single sprinkler in this test therefore effects of adjacent sprinklers have been considered by assuming identical climatic conditions and propagation pattern around sprinkler and employing of simulation technique and distribution uniformity was calculated by Christiansen’s uniformity coefficient.

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And finally values of water distribution uniformity and Christiansen's uniformity coefficient calculated by simulation technique were analyzed for water pressure and different wind speeds by means of SPSS software.

RESULTS AND DISCUSSION

According to [Table 1], water distribution uniformity coefficient has been increased with rise of pressure (from 2.2 to 4.7 atmospheres) and this was not linear relation but it has greater gradient at low pressures (2.2- 3.5 atmospheres) than high pressures (3.5- 4.7 atmospheres).

As it seen in [Table 1], when pressure is increased from 2.2 atmospheres up to 50% and reached to 3.5 atmospheres, uniformity coefficient is increased 4.9% but if pressure is increased 113.6% and 4.7 atmospheres, uniformity coefficient increases 5.6%. It is observed this relationship is not linear and gradient of this curve is greater at lower pressures. Based on studies of Christiansen [24], as water pressure is reduced at any specific sprinkler, intensity of propagation becomes greater (discharge and radius of propagation is reduced with decrease in pressure but effect of reduction of area is greater than reduction of discharge and this is led to rise of propagation intensity) and also intensity of blow by water drops increases on soil while water distribution uniformity is reduced. Particles are pulverized at higher pressures and easily carried by wind and therefore uniformity is reduced. Likewise, drops exiting from sprinkler fall near to it at lower pressures and they create weak sprinkling profile where this is also led to reducing uniformity coefficient.

Table 1: Effect of operational pressure on water distribution uniformity in trickle irrigation system

Pressure (Atmosphere)	Uniformity coefficient (%)	Percent of pressure rise compared to pressure 2.2 atmosphere	Percent of uniformity rise compared to pressure 2.2 atmosphere
2.2	81.5	-	-
3.5	87.5	59.1	4.9
4.7	86.1	113.6	5.6

Table 2: Regressive equations for estimation of uniformity coefficient using sprinkler operational pressure

R2	Equation for estimation of uniformity coefficient in respective of operational pressure	Wind speed
0.8705	Y= 1.9776x + 82.478	2km/h
0.8746	Y= 1.7335x + 81.491	3km/h
0.8982	Y= 1.7335x + 81.491	5km/h
0.8642	Y = 1.8166x + 79.202	6.5km/h
0.7466	Y = 2.5544x + 71.612	7km/h
0.7016	Y = 1.2996x + 70.328	11km/h

Analysis of the given results from water distribution uniformity under different pressures signifies that there is significant difference between the studied pressure values at level 5%. Review on relationship among sprinkler pressure and mean of water distribution uniformity for all the given wind speeds showed in this study that when pressure level was increased from 2.2 atmospheres to 3.5 atmospheres (59%), water distribution uniformity was also added up to 4.9% but rise of pressure from 3.5 to 4.7 atmospheres indicates only 0.5% increase in water distribution uniformity. These findings suggest that there is no linear relationship among pressure and water distribution uniformity while gradient of this curve is greater at low pressures so these findings are consistent with the results of studies done by other researchers. Although pressure level greater than 4.7 atmospheres has not been tested in this study, the trend of increase in water distribution uniformity versus rise of pressure signifies that rise of pressure more than 4.7 atmospheres will not have noticeable effect on uniformity of water distribution. Based on studies of Christiansen, as pressure lessens in any specific sprinkler, discharge and radius of propagation is reduced in sprinkler but the effect of reduction of level will be greater than reduction of discharge and as a result intensity and pattern of distribution exits from favorable state and this is led to problem of reducing uniformity of water distribution. Based on results of this study, relatively high propagation of water in environmental areas is the most efficient factor in reducing uniformity coefficient at low pressure (2.2 atmospheres). Rise of pressure decreases water propagation in environmental areas and propagation pattern is relatively corrected and this causes rise of uniformity in water distribution. Although appropriate pressure varies depending on type of sprinkler, generally if pressure level is selected among 3.5 to 4.7 atmospheres in the studied sprinkler, value of uniformity coefficient will be higher than 80% that has been recommended by many researchers as a suitable criterion for trickle irrigation systems. However if pressure level is selected lesser than 3.5 atmospheres, uniformity coefficient will be decreased according to the above-said reasons. Although in order to find appropriate pressure it is recommended to examine wider range of pressure, due to pulverization of water particles under pressure higher than 4.7 atmospheres and effect of wind speed on these particles, higher pressure than this [Fig. 1] is not recommended for the given sprinkler [5-7].

CONCLUSION

It is recommended that if pressure level is lower, sprinklers should be placed within smaller distances. Based on this study, relatively high propagation of water within perimeter of distribution circle is the most efficient factor in reducing uniformity coefficient at low pressure. Rise of pressure may decrease high propagation of water within perimeter of distribution circle (it adjusts propagation pattern to some extent) and it causes increase in uniformity coefficient. If pressure value is selected about 3.5-4.7 atmospheres in the given sprinkler, uniformity coefficient will be greater than 80% that is accepted by many designers. Results came from this study are consistent with the given findings by other researchers who have worked on medium and high pressures.

The reciprocal effect of sprinkler type and pressure suggests that water distribution uniformity is added following to rise of pressure in any sprinkler but this trend is not linear within range of studied pressure.

CONFLICT OF INTEREST

There is no conflict of interest.

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None

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