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Technical Evaluation of Sprinkler Irrigation Systems in Arak, Iran

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Abstract: The scarcity of water resources is one of the crises most commonly experienced in different regions of the world especially in Iran. By the implementation of pressurized irrigation projects in this region, it is likely to enhance the consumption efficiency. One of the indispensable components in any irrigation exercise in order to improve the irrigation systems is evaluation activity. In the present study, nine different sprinkler irrigation systems i.e., the solid set system and wheel move systems in the Arak agricultural area, Iran were selected, tested and evaluated. Values of Coefficient Uniformity (CU), Distribution Uniformity (DU), Potential Efficiency of Water Application (PELQ), Actual Potential Efficiency of Water Application (AELQ) and maximum pressure difference (ΔPmax) in solid set systems are 76.16, 64.53, 55.56, 51.48 and 45.23%, respectively and for wheel move systems are 82.86, 76.02, 67, 67 and 29%, respectively. Average losses due to wind and deep percolation values were determined as 12.78 and 32.83%, respectively for solid set systems and 12.22 and 2.53%, respectively for wheel move systems. In solid set systems all of parameters failed to meet the expected values, however wheel move systems showed a better performance with mild wind. In general, it can be claimed that the main problems of sprinkler irrigation systems are deficient design and implementation, low distribution uniformity, low water pressure, deficient distribution of pressure, insufficient lengths of lateral pipelines in addition to poor quality equipment utilized and deficient management and maintenance processes.

Key words: Sprinkler irrigation, uniformity, efficiency, solid set, wheel move

INTRODUCTION

Due to low precipitation and its disproportional distribution in terms of time and space, Iran is located in arid and semi arid regions where almost 94% of abstractions from renewable resources are allocated to agricultural sector. The overall irrigation efficiency in this sector on average is estimated as 30 to 35%. Where by implementing pressurized irrigation projects the consumption efficiency can be considerably enhanced to improve the existing values. One of the inseparable exercises in irrigation projects is to be evaluation. Irrigationevaluation is defined as analysis of any irrigation method which is based upon the measurements takes under actual conditions of a land (Anonymous, 1997).

Baghbani (1995) reviewed the influences of varieties of sprinklers heights on evaporation and drift losses in center pivot irrigation systems and concluded that with a wind velocity of 2 m sec^{-1}, should the height of sprinklers be reduced from 2.25 to 1.65 m, the evaporation and drift losses would be reduced by 50%. Ataee (1997) studied a number of pressurized irrigation system in different point of Isfahan, Iran and achieved a potential efficiencies for drip and sprinkler irrigation systems between 18 to 70% and 28 to 62%, respectively with actual efficiencies of 51 and 37%, respectively. Ebrahimi (1996) evaluated different wheel move irrigation systems in Mashhad and Torbate-e Heidarieh regions in Iran and attained actual efficiency of 54 to 62%. Tarjuelo *et al*. (2000) designed a model to calculate the evaporation and wind losses in a semi arid environmental where the influences of factors such as the type of the riser, nozzle composition, vapor pressure deficit and wind velocities were considered. They concluded that with an increase of wind velocity up to 20 km h^{-1}, the distribution uniformity decreased nonlinearly and declined afterward. Jiusheng (1998) presented a simulation model including the effect on crop yield of both sprinkler uniformity and water deficit. Ayers *et al*. (1991) studied sugar beet and cotton yield response to the uniformity of a linear-move sprinkler irrigation system that can generate different uniformities and scales of variation. The last two studies have shown important effects of the non-uniformity pattern on crop yield.

MATERIALS AND METHODS

In the present study, two different irrigation systems i.e., solid set irrigation system and wheel move irrigation system, two soil textures (loamy and fine) and two crop fields namely alfalfa and potato were utilized under the same environmental conditions. The experiments were

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Table 1: Characteristics of the sprinkle irrigation systems

Type of system	Crop	Area (ha)	Water supply	Lateral pipes or sprinklers in operation	Sprinklers spacing m×m	System code
Solid set	Alfalfa	100	Well	12	21×33	GK_1
Solid set	Potato	25	Well	6	21×25	GK_2
Solid set	Potato	15	Well	4	25×25	MK_1
Solid set	Potato	48	Well	7	25×25	MK_2
Solid set	Potato	24	Well	6	25×27	VK
Wheel move	Potato	50	Well	3	12×15	AW_1
Wheel move	Potato	100	Well	3	12×18	AW_2
Wheel move	Potato	250	Well	1	12×18	MW_1
Wheel move	Potato	88	Well	2	12×15	MW_2

conducted in Arak agricultural region center of Iran, during year of 2004. Table 1 reflects the characteristics of both irrigation systems. This study mainly focuses upon the technical evaluation of the performance of the two sprinkle irrigation systems. All of the experiments were undertaken in moderate environmental conditions while the average wind velocity was less than 6 km h^{-1}.

In order to evaluate the both systems, initial data and information were collected upon topography, features of water supplies, pumping, main pipes, semi main and lateral pipes, characteristics of the sprinklers, opening and closing values and detailed drawings of the joints. Soil and planting parameters including soil texture, soil density, soil moisture before any irrigation exercise to estimate Soil Moisture Deficit (SMD), soil moisture in Field Capacity (FC), soil infiltration and root zoon depth were measured. Environmental parameters such as wind velocity and direction, relative humidity and temperature were collected. The sprinklers discharge and pressure were also measured. For measuring water distribution one of the lateral pipes was selected initially then pooling buckets were placed with space of 3×3 m between two moderate pressure sprinklers. The time of the experiment was between 1 to 2 h depending on the farm conditions. Eq. 1 was used to obtain the coefficient uniformity:

$$CU_t = \left(1 - \frac{\sum |D_i - \bar{D}|}{\bar{D} \times n}\right) \times 100 \qquad (1)$$

Where:

D_i = The water depths in each bucket in mm,

$\bar{D}$ = The average of the water depths in mm

n = The number of observation.

To attain the potential efficiency of water Eq. 2 was applied.

$$PELQ_t = D_q / D_r \times 100 \qquad (2)$$

Where:

D_q = The average of one fourth the lowest water depth infiltrating into the soil which is equal to maximum discharge in mm

D_r = The average irrigation water depths in mm.

The values determined for the parameters above should be adjusted considering the pressure differences in the system being valid enough to be applied for the entire system. The distribution of the system is as follow:

$$CU_s = CU_t \left[\frac{1 + \left(\frac{P_{min}}{P_{mean}} \right)^{0/5}}{2} \right] \qquad (3)$$

where, index (S) relates to the system and index (t) is related to testing block, P_{max}, P_{mean} and P_{min} are maximum, average and minimum pressure, respectively inside the irrigation system. After the parameter required were obtained, the evaluation parameters were calculated using the related equations.

RESULTS AND DISCUSSION

Table 2-5 show the evaluation parameters calculated for sample systems where differences between actual efficiencies and potential efficiencies reflect the management state of the systems. Other parameters show the design and excision of the systems.

Coefficients of uniformity in the testing blocks in GK_2, MK_2, VK, AW_1, AW_2, MW_1 and MW_2 were more than 80%. Appropriate selection of the types of sprinklers, spacing, efficient functional pressure of sample sprinklers and ideal weather conditions during the sampling led to the increase of distribution coefficient and distribution uniformity in these systems compared to those of the other systems. Distribution coefficient and uniformity in GK_1 and MK_1 systems was much less than those of the other system which was because of aging and exhaustion of the systems insufficient spacing of sprinklers, crookedness of the sprinklers risers also, high pressure differences along the lateral pipes in the GK_1 system and through the MK1 system, inefficient relation of sprinklers due to insufficient pressure and inadequate overlapping of sprinklers. Pressure variances in most of the sampling systems where in and acceptable range except for the GK1 and AW_2 systems, thus the distribution and coefficient uniformity to the entire system

Table 2: Results of evaluation parameters in the solid set sprinkle systems

System code	Average infiltration rate (mm h^{-1})	Intensity of sprinkler discharge (mm h^{-1})	Average discharge of the sprinklers (L h^{-1})	Application efficiency of the system (%)	(CU) of the system (%)	Application efficiency of the block (%)	(CU) of the block (%)
GK_1	13.50	16.98	3.27	39.86	67.4	48.0	71
GK_2	18.20	20.16	2.94	55.12	83.1	67.3	85
MK_1	14.23	15.55	2.70	43.98	66.7	46.4	68
MK_2	15.60	17.16	2.98	61.66	78.2	64.7	81
VK	15.57	18.56	3.48	56.78	85.3	67.6	88

Table 3: Pressure variations in the solid set sprinkle systems

System code	$\frac{\Delta P}{P_a}$(%)	P_{min} (Bar)	P_{max} (Bar)	$\bar{P}$ (Bar)
GK_1	45.23	3.40	5.3	4.2
GK_2	22.22	4.10	5.1	4.5
MK_1	25.93	2.50	3.2	2.7
MK_2	23.68	3.30	4.2	3.8
VK	26.14	3.95	5.1	4.4

Table 4: Results of evaluation parameters in the wheel move systems

System code	Average infiltration rate (mm h^{-1})	Intensity of sprinkler discharge (mm h^{-1})	Average discharge of the sprinklers (L h^{-1})	Application efficiency of the system (%)	(CU) of the system (%)	Application efficiency of the block (%)	(CU) of the block (%)
AW_1	13.40	14.80	0.74	63.39	78.96	66.31	81.6
AW_2	6.68	7.66	0.46	71.38	86.36	75.78	91.0
MW_1	9.10	10.33	0.62	69.38	85.31	72.20	87.7
MW_2	7.68	9.00	0.45	64.00	80.82	66.70	82.5

Table 5: Pressure variations in wheel move sprinkle systems

System code	$\frac{\Delta P}{P_a}$(%)	P_{min} (Bar)	P_{max} (Bar)	$\bar{P}$ (Bar)
AW_1	22.0	2.80	3.5	3.2
AW_2	29.0	2.50	3.4	3.1
MW_1	19.7	2.95	3.6	3.3
MW_2	20.0	2.30	2.8	2.5

Table 6: Comparison of the two systems

		Whole system		Experiment block	
System type	System code	CU (%)	Application potential efficiency (%)	CU (%)	Application potential efficiency (%)
Solid set	GK_1	67.44	43.68	71.0	48.00
	GK_2	83.10	64.36	85.0	67.32
	MK_1	66.72	43.98	68.0	46.40
	MK_2	78.24	61.66	81.0	64.70
	VK	85.30	64.10	87.6	67.60
	Avg.	76.16	55.56	78.5	58.80
Wheel move	AW_1	78.96	63.39	81.6	66.31
	AW_2	86.36	71.38	91.0	75.78
	MW_1	85.31	69.38	87.7	72.20
	MW_2	80.82	64.00	82.5	66.70
	Avg.	82.86	67.00	85.7	70.25

were not lower than the measured values at sampling blocks. Pressure variance through the GK1 system was more than the maximum allowable friction losses due to the excessive length of lateral pipes despite there adequate stop to compensate for pressure losses hence the coefficient unity and distribution uniformity decreased throng entire system. Table 6 reflects the average distribution coefficient and potential efficiencies of water application for both solid set sprinkler and wheel move systems. It can be inferred that the values of the aforementioned parameters are considerably higher for wheel moves than solid set systems.

With due regard to the fact that the areas for both types of the systems and the number of operating sprinklers at the same time were not similar, pressure and sprinklers efficiencies were different in the both systems thus comparing two systems on the surface of the experimental block would result in more accurate data. It can be concluded that for the experimental block, coefficient uniformity and potential efficiencies of water application in the wheel move systems were higher than those in the solid set systems. However in high wind velocity conditions, heavy soil texture with high degree of cohesion performance of the wheel move irrigation system is much weaker than the solid set system. Since by selecting adequate time step and sufficient irrigation the actual efficiency of the system can be enhanced enough to meet the potential efficiency. Of note is that the scarcity of water resources causes low irrigation which in turn increases the potential efficiency values.

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