SPRAY LOSSES IN SPRINKLER IRRIGATION SYSTEMS IN IRAQ

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ABSTRACT

Similar to all other methods of irrigation, sprinkler irrigation has its own advantage and disadvantage, one of the major problems associated with using sprinkler irrigation is the effect of wind, which causes large percentage of spray loss and distortion profiles. In this research, fieldwork has been carried out at Al-Raeed STATION in ABU-GRAIB to analyze the performance of sprinkler irrigation system under local real conditions.

Different flows through three double nozzle sizes, wide range of operating pressure from (1.25 bar) to (4.0 bar) and unpredictable wind speed, were investigated.

The spray loss was assumed to be a function of nozzle diameter, discharge, operating pressure, wind speed, and relative humidity. A dimensional analysis technique was used to develop a prediction equation, the correlation coefficient between predicted and observed spray loss values was about (0.93), which seem to be acceptable.

INTRODUCTION

In many cases where irrigation is practiced, and particularly where sprinkler system are installed, water supplies are limited and water cost is high. It is, therefore, of paramount importance to define the factors influencing sprinkler irrigation efficiency; to high functional equipment, methods, and systems, and to define the sprinkling conditions led to increase efficiencies.

Loss of water between the sprinkler nozzle and the irrigate crop is usually divided into tow component: (a) Evaporation during sprinkling and (b) drift losses (out of the irrigation area). These losses vary with climatic conditions such was wind speed, relative humidity, air temperature, and also equipment and operating conditions such as nozzle and operating pressure.

FIELD EXPERIMENT AND DATA

The conducted fieldwork has included (23) experiments, each of which covered a given set of irrigation and climatologically conditions. In each of these tests, one sprinkler head was operated only. This operation scheme was followed to avoid spray overlapping from neighboring sprinklers and to obtain a good picture of the equivalent wetted diameter and wetting pattern.

Furthermore, this scheme helps to predict system performance for various sprinklers and lateral spacing.

These experiments were carried out by keeping all pertinent factors almost fixed and one of them changed.

Accordingly, in arranging the field experiments all the variables remained unchanged but the following have been taken into construction:

* The nozzle diameters used are (6.0 × 3.1 mm) (4.5 × 3.0 mm) and (8 × 4.0 mm).
* The operating pressure used was changed from (1) bar to (4) bars.
* The wind speed used was 5, 10 and more than 10 kph. Such limited wind brackets are selected due to difficulty of precisely controlling the wind speed in the field.

DEVELOPMENT FOR PREDICTING SPRAY LOSSES

In this research it was attempted to develop an empirical relationship to predict spray loss from sprinkler by using operating and climatological data. In this work, dimensional analysis has been utilized using the pi-theorem. In doing so, the percentage of water drifted during spraying was assumed to be a function of sprinkler discharge, wind speed, relative humidity, operating pressure, gravity action, and nozzle diameter, in other word:

$$L = f(Q, Ws, Hu, P, g, N_d) \quad (1)$$

where:

L = Percentage of water lost during spraying
F = Functional operator
Q = Sprinkler discharge, L^3T^{-1}
Ws = Average wind speed during sprinkling, LT^{-1}
Hu = Average relative humidity during Sprinkling, %
P = Operating pressure head, L
g = Acceleration due gravity, LT^{-2}
N_d = Sprinkler diameter, L

Equation (1) can be expressed by a general relationship of the following form:

$$L = C' \, Q^{C1} \, Ws^{C2} \, P^{C3} \, g^{C4} \, N_d^{C5} \, Hu \quad (2)$$

Where C' to C_5 are constant, by using dimensional analysis and recalling that Hu and L are dimensionless, the following relationships can be written among the constant C' to C_5:

$$3C_1 + C_2 + C_3 + C_4 + C_5 = 0 \qquad \text{for L} \tag{3}$$

$$-C_1 - C_2 - 2C_4 = 0 \qquad \text{for T} \tag{4}$$

Since there are two equations and five unknowns, it obvious that there are infinite solutions depending on the values assigned. Thee of the unknowns are therefore arbitrary values to be assigned C_1, C_2 and C_3 for instance the corresponding values of C_4 and C_5 are computed accordingly. Assuming that $\Pi_1 = L$ and $\Pi_5 = Hu$, the remainder of the Π-terms are calculated as shown in Table 1.

Table 1 Л- terms computation by assigning arbitrary values to constants

Assigned Values			Computed Values		Л- terms
C_1	**C_2**	**C_3**	**C_4**	**C_5**	
1	0	0	-1/2	-5/2	$\frac{Q}{N_d^{5/2} g^{1/2}} = \Pi_2$
0	1	0	-1/2	-1/2	$\frac{W_S}{\sqrt{N_d g}} = \Pi_3$
0	0	1	0	1	$\frac{P}{N_d} = \Pi_4$

Thus, Equation (1) can be re-written in the following dimensionless form:

$$\Pi_1 = f(\Pi_2, \Pi_3, \Pi_4, \Pi_5) \tag{5}$$

However, sprinkler discharge, pressure head, and nozzle diameter are all through the orifice equation as follows:

$$C_d = \frac{Q}{A_s \sqrt{2\,g\,p}} \tag{6}$$

Where:

C_d = discharge coefficient

A_s = cross-sectional area of the nozzle (L^2)

So if Π_2^2 is divided by Π_4, a term similar to Equation (6) can be obtained, therefore, Equation (5) can be further reduced to:

$$\Pi_1 = f(\Pi_{2,4}, \Pi_3, \Pi_5) \qquad (7)$$

In order to obtain a relationship between Π_1 and the other Π_1 term, the calculated spray losses for each test and the operating and climatic are present in Table (2).

Table 2 Summary of field data, actual and predicted spray losses for the conducted test

Form No.	Discharge	Pressure	Wind Speed	Humidity	Temperature	Nozzle diameter	R.H	Predicted Losses	Actual Losses
	m^3/s	m	m/s	%	°C	mm	m	%	%
1	3.8×10^{-4}	12.50	1.833	37.0	30.0	6.0×3.1	0.65	20.02	21.00
2	4.0×10^{-4}	5.00	1.805	36.5	31.0	6.0×3.1	0.65	19.67	22.20
3	5.0×10^{-4}	20.00	2.027	33.0	28.5	6.0×3.1	0.65	24.97	24.41
4	5.5×10^{-4}	25.00	3.330	37.0	29.0	6.0×3.1	0.65	23.81	25.80
5	6.0×10^{-4}	30.00	0.972	27.0	29.5	6.0×3.1	0.65	29.40	31.45
6	6.2×10^{-4}	32.50	2.000	27.5	34.0	6.0×3.1	0.65	35.96	39.75
7	6.5×10^{-4}	35.00	1.660	29.5	33.0	6.0×3.1	0.65	30.46	30.96
8	7.8×10^{-4}	40.00	1.944	29.0	33.0	6.0×3.1	0.65	29.30	31.77
9	3.0×10^{-4}	12.50	1.944	42.0	28.5	4.5×3.0	0.65	13.00	12.50
10	3.2×10^{-4}	15.00	2.388	42.0	28.5	4.5×3.0	0.65	14.17	13.50
11	3.8×10^{-4}	20.00	3.050	45.0	27.0	4.5×3.0	0.65	13.15	15.80
12	3.9×10^{-4}	22.50	3.000	36.0	27.0	4.5×3.0	0.65	20.53	23.00
13	4.0×10^{-4}	25.00	3.110	36.5	22.5	4.5×3.0	0.65	20.65	23.83
14	4.3×10^{-4}	30.00	2.138	40.0	29.0	4.5×3.0	0.65	15.60	12.41
15	4.8×10^{-4}	35.00	2.222	43.0	31.0	4.5×3.0	0.65	13.42	15.80
16	5.6×10^{-4}	40.00	1.944	32.5	31.0	4.5×3.0	0.65	20.55	26.00
17	6.8×10^{-4}	15.00	3.055	56.0	25.0	8.0×4.0	0.65	10.87	10.58
18	7.5×10^{-4}	20.00	3.000	55.0	26.0	8.0×4.0	0.65	11.58	15.54
19	9.4×10^{-4}	25.00	2.000	36.0	35.0	8.0×4.0	0.65	20.97	21.56
20	10.3×10^{-4}	30.00	1.250	45.0	25.0	8.0×4.0	0.65	11.78	11.48
21	11.5×10^{-4}	35.00	0.972	32.0	30.0	8.0×4.0	0.65	20.33	22.75
22	12.4×10^{-4}	40.00	1.944	32.0	29.0	8.0×4.0	0.65	25.21	25.17
23	12.5×10^{-4}	40.00	2.000	30.5	31.0	8.0×4.0	0.65	27.72	24.97

The collected data were sorted combination by using the least-square method, a relationship has been found between spray loss and the considered variable Π-term. The developed relationship is expressed as following:

$$\Pi_1 = 22.94\,\Pi_{2,4}^{-1.177} \qquad (8)$$

$$\Pi_1 = 64.26\,\Pi_3^{0.51} \qquad (9)$$

$$\Pi_1 = 1.146\,\Pi_5^{-3.0} \qquad (10)$$

By substituting Equations (8), (9) and (10) in Equation (7) and assuming that the functional relationship (7) is multiplication it can be shown that:

$$\Pi_1 = 1690.083\, K \left[\Pi_{2,4}^{-1.177}\ \Pi_3^{0.51}\ \Pi_5^{3.0}\right] \quad (11)$$

or

$$\Pi_1 = K\, B \quad (11a)$$

where: K = constants. The values of B are calculated by using actual field data and respective values of K calculated as the quotient of actual spray loss and the calculated B values. A relationship is found again by using the least-square method. The relationship is expressed by:

$$K = 1148.396\ \Pi_{51}^{-0.572} \quad (12)$$

By combining Equations (11) and (12) and simplifying, it can be shown that:

$$\Pi_1 = 10^3 \left[\Pi_{2,4}^{-0.75}\ \Pi_3^{-0.32}\ \Pi_5^{-1.91}\right] \quad (13)$$

$$L = 10^3 \left(\frac{Q}{N_d^2 \sqrt{Hg}}\right)^{-0.75} \left(\frac{Ws}{\sqrt{N_d\, g}}\right)^{-0.32} (Hu)^{-1.91} \quad (14)$$

RESULT AND DISCUSSION

Comparison of Predicted and Field Spray Losses

The developed Equation (14) was used to predict spray loss using the field data; Table 2 presents the values of the actual and predicted spray loss for each test also the operating and climatic condition.

The predicted and actual values of spray losses for all field tests are plotted in Figure (1) deviation from 45° angle line shows the degree of difference. The correlation coefficient between the two values was found to be (0.936), which is fairly acceptable value.

Comparison between Many Previous Local Equations Developed for Predicting Spray Losses

As it can be seen from the results in Table 3, the developed formula predicts spray losses with an acceptable degree of accuracy among many other researcher equations. Figures (2) to (7) show plots between filed and predicted spray losses using data from many sources, these plots indicated fair agreements between measured and predict values.

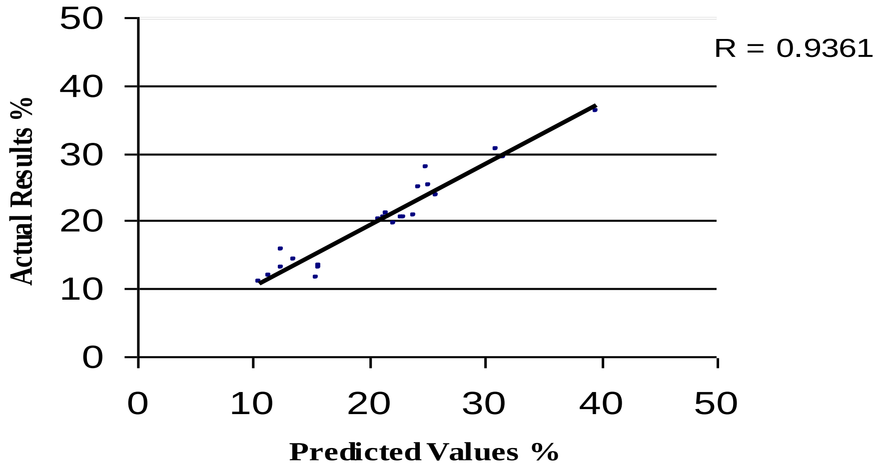

Figure (1) Comparison of predicted and actual spray losses

Table 3 Measured and predicted spray losses using present equation and other previous ones

Measured spray losses	**Predicted spray losses %**				
	Ahmed	**Jajo**	**Dawood**	**Mzahem**	**Present**
▪ 22.60	17.21	10.31	15.50	9.13	22.42
▪ 13.71	22.31	13.90	14.36	15.85	13.86
▪ 29.81	17.55	22.65	21.69	39.80	27.18
❖ 24.41	27.65	12.02	16.82	11.83	24.97
❖ 25.80	34.71	16.43	20.43	20.80	23.81
❖ 31.45	23.23	14.05	16.63	13.87	29.40
❖ 25.17	9.77	17.15	18.90	30.70	25.21
- 22.60	17.21	10.31	15.50	9.13	22.42
- 29.80	17.55	22.65	21.69	39.80	27.18
• 10.00	11.29	7.62	11.59	7.48	13.52
• 12.00	12.47	10.02	12.15	11.61	15.67
• 18.00	17.99	19.89	17.00	26.56	23.40
☑ 20.00	Not	20.73	14.39	7.67	21.28
☑ 40.00	Not	Not	32.55	61.25	40.81
☑ 38.00	Not	Not	30.07	46.51	39.35
⌑ 26.00	Not	24.68	16.09	18.18	28.57
⌑ 14.00	Not	18.16	8.31	14.08	15.63
⌑ 17.00	Not	22.93	10.69	21.25	18.51

▪ Data from Ref. (1)
❖ Data from present field work
- Data from Ref. (2)
• Data from Ref. (6)
☑ Data from Ref. (4)
⌑ Data from Ref. (8)

The predicted and measured values of spray losses for all field tests are plotted in Figure (1): deviation from 45° angle shows the degree of different. The correlation coefficient between the values was found to be (0.936), which is a fairly acceptable value.

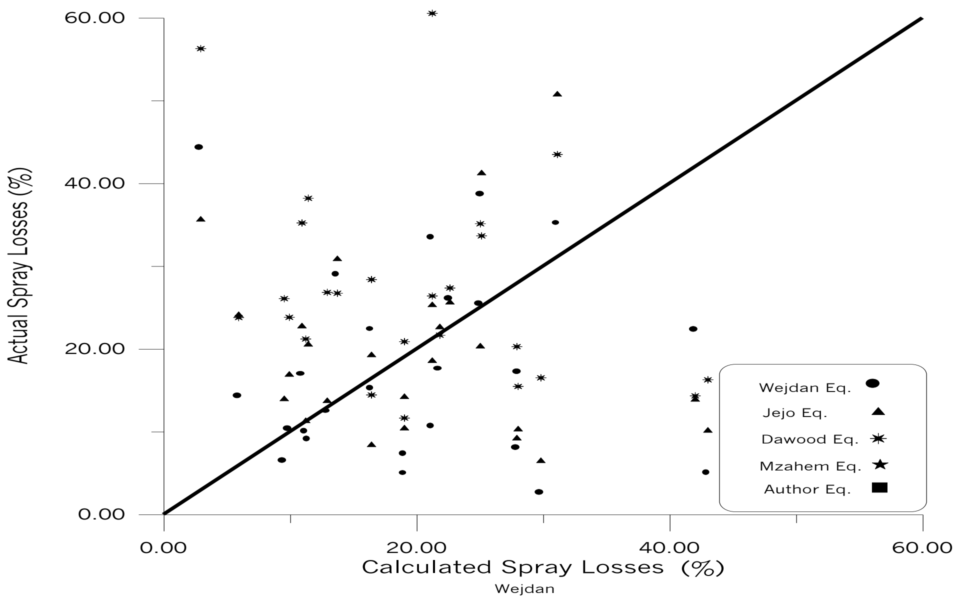

Figure (2) Comparison between actual and calculated spray losses for the data from Ref. (1)

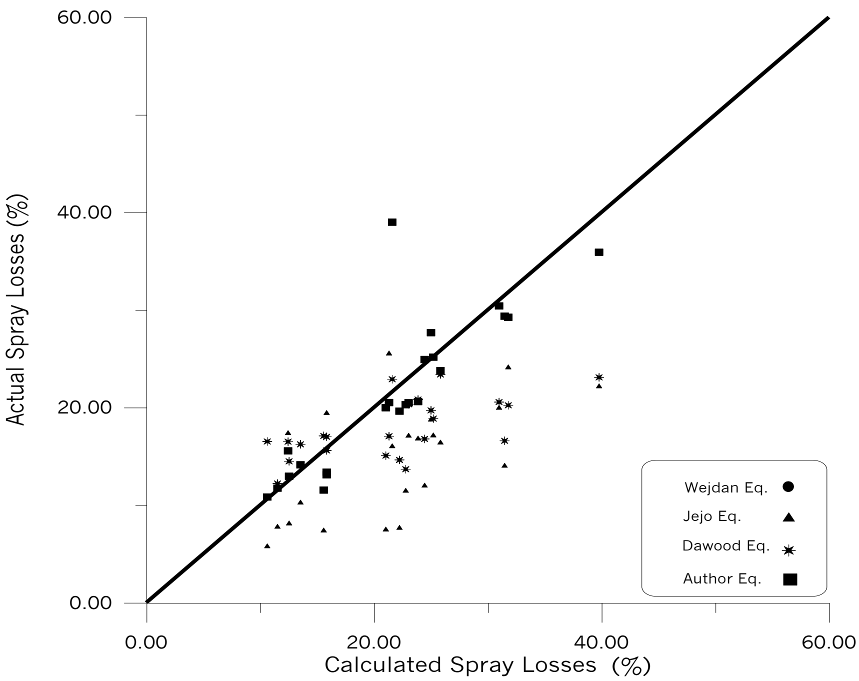

Figure (3) Comparison between actual and calculated spray losses

for the data of the present field work

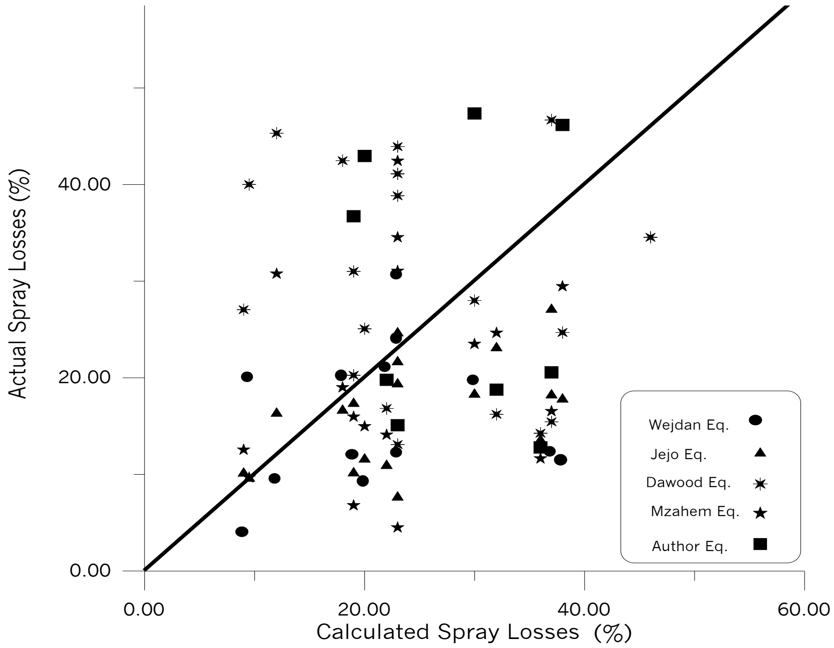

Figure (4) Comparison between actual and calculated spray losses for the data from Ref. (2)

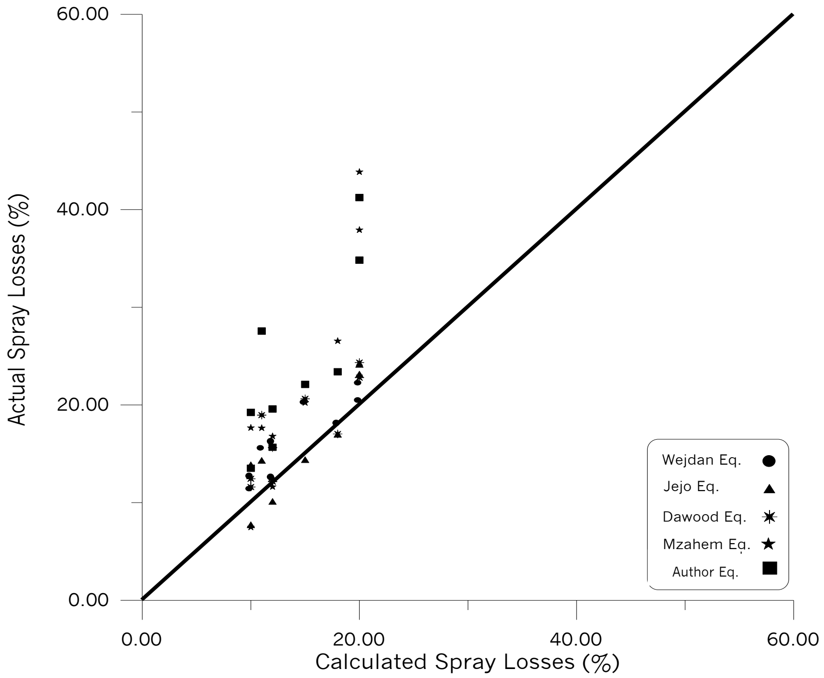

Figure (5) Comparison between actual and calculated spray losses for the data from Ref. (6)

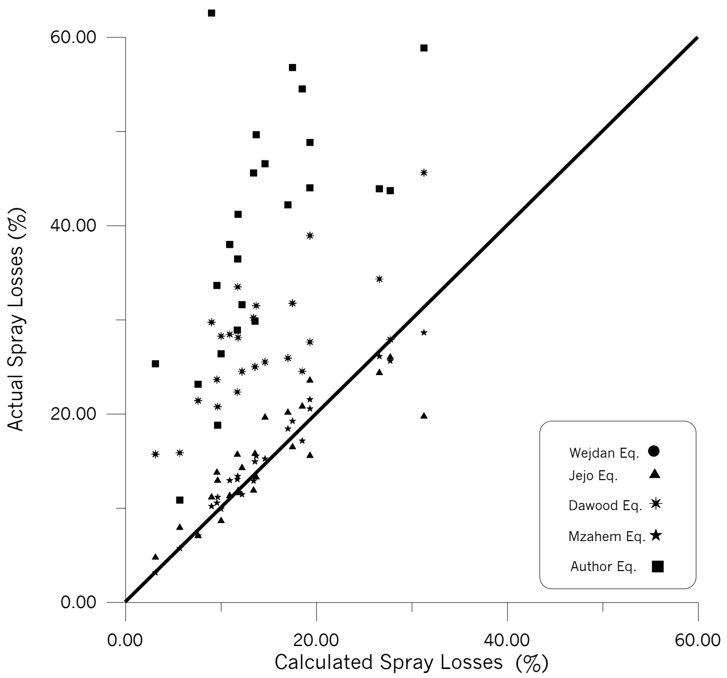

Figure (6) Comparison between actual and calculated spray losses for the data from Ref. (4)

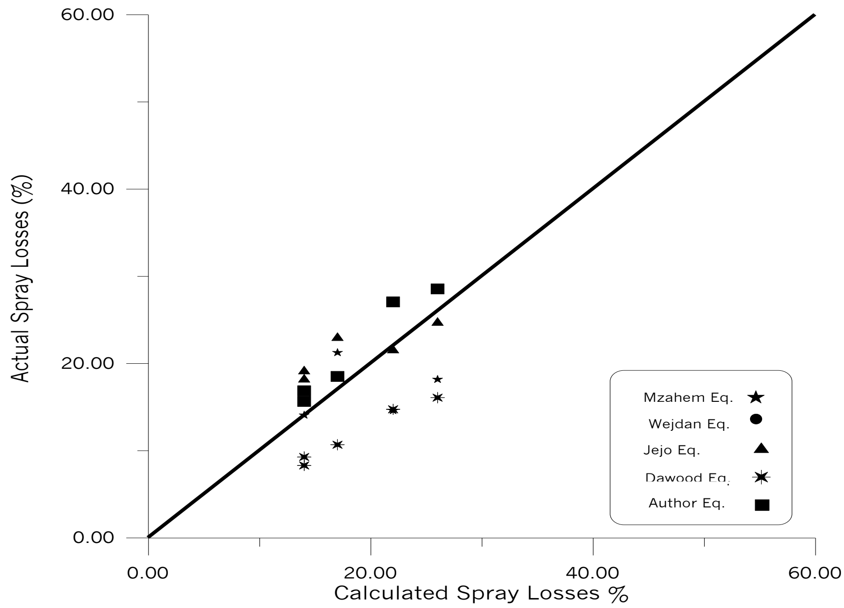

Figure (7) Comparison between actual and calculated spray losses for the data from Ref. (8)

SUMMARY AND CONCLUSIONS

In this work a field test has been performed to investigate the performance of locally operated sprinkler irrigation systems.

High spray losses from sprinkler irrigation under sever climatic conditions are one of the disadvantages of sprinkler irrigation.

In this paper, it was intended to develop a relationship for predicting spray loss from fixed-grid sprinkler system by using dimensional analysis. The developed relationship expressing spray loss as a function of dimensionless combination of sprinkler discharge, operating pressure, nozzle diameter, wind speed, and relative humidity. The effect of temperature variation was not included because the range of variation of temperatures during the experimental time was very limited (30-40°C).

The developed equation was used to predict spray losses and was compared with field measurements. Excellent agreement was observed between measured and predicted values.

As many other Iraqi researcher had been worked in the same field, but in different locations, it became necessary to compare the available results, all together, in order to evaluate the present work, in the first hand, and to recommend the more representative equations in the other hand.

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