# Journal of Applied Sciences

ISSN 1812-5654

science alert

ANSInet
an open access publisher
http://ansinet.com

Journal of Applied Sciences 9 (3): 597-600, 2009
ISSN 1812-5654


# Evaporation Losses from Sprinkler Irrigation Systems under Various Operating Conditions

[1]A. Bavi, [1]H.A. Kashkuli, [1]S. Boroomand, [1]A. Naseri and [2]M. Albaji
[1]Department of Irrigation and Drainage, Faculty of Water Sciences Engineering,
University of Shahid Chamran, Ahwaz, Iran
[2]KWPA, Ahwaz, Iran

**Abstract:** The sustainability of irrigated agriculture depends upon consistently achieving high irrigation application efficiency. In semi-arid areas, the portion of water that might be lost due to wind and evaporation would be significant. Thus a proper understanding of factors affecting spray losses (Ls) in sprinkler irrigation is important for developing water conservation strategies. The objectives of this study include: characterize Ls under different weather conditions and operating pressures for semi-portable hand move sprinkler system in western south of Iran (Khuzestan Province); propose adequate predictive equations by using multiple regression and Suggest several recommendations for helping about design and management for sprinkler irrigation system in semi-arid areas. The results showed that wind velocity and vapor pressure deficit were the most significant factors affecting the evaporation losses. Exponential relationships between the evaporation losses and both wind velocity and vapor pressure deficit have been found. For the operating pressures used in this study the least effect on evaporation was found. Combined losses from a sprinkler system for a given set of operation conditions have been estimated by using the results obtained from the experiments. Combined losses ranged from 4.4 to 8.9% of the applied water.

**Key words:** Wind velocity, droplet, catch-containers, vapor pressure deficit, hand move sprinkler

## INTRODUCTION

As the necessity, for conservation of water resources increases, especially in areas of limited water supply, more precise knowledge about application efficiencies of sprinkler irrigation systems is required. Irrigation principles and practices for sprinkler irrigation have advanced to the point that water application efficiency is primarily controlled by the amount of evaporation and drift losses. More knowledge about water losses associated with sprinkler irrigation can significantly help towards assessor the overall application efficiency. Water can be applied at any suitable rate by sprinkler irrigation system during the day or night. The efficiency of the sprinkler irrigation depends on the losses which take place during and following the irrigation. When water conditions, some of the spray droplets are carried away from the sprinkled area, where a portion of it is intercepted by vegetation or by bars soil outside the sprinkled area.

Losses from sprinkler irrigation in arid and semi-arid areas may amount to a considerable portion of the water discharged by sprinklers. The magnitude of evaporation and drift losses depends upon the climatic and operating conditions. To obtain an insight into the magnitude of these losses, it is of paramount importance to find the factors affecting them. If these relationships can be determined, the conditions for sprinkling can be defined and functional equipment may be designed. This report describes the results of evaporation and drift-loss experiments conducted under different operating conditions in order to determine the relationships between the losses and the factors affecting them.

Christiansen (1942) determined evaporation losses by utilizing the catch-can method and found that losses ranged from 19 to 42%. However, no correlations of losses with climatic variables were reported. Frost and Schwalen (1955) found that losses vary approximately proportional to wind velocity and operating pressure and inversely proportional to relative humidity of the air and nozzle size. A close relationship between losses and vapor pressure deficit of the air was also obtained by these researchers. While, Frost and Schwalen (1955) found spray losses as high as 45% under extreme conditions of bright sunlight, high temperatures and low humidity prevailing in Arizona, other authors signaled maximum losses of 30% (Yazar, 1984). Hermsmeier (1973), using the salt-concentration technique, found that air temperature and rate of application were better factors for estimation spray evaporation than wind velocity or relative humidity. Yazar (1984) estimated evaporation losses from the sprinkler irrigation under various operating conditions from the

**Corresponding Author:** A. Bavi, Department of Irrigation and Drainage, Faculty of Water Sciences Engineering, University of Shahid Chamran, Ahwaz, Iran

electrical conductivity measurement of the supply water and the water in the catch-containers and found that wind velocity and vapor pressure deficit were predominant factors affecting evaporation losses. Scientific literature has treated the problem of spray evaporation as one of minor relevance, mainly attributing to wind drift the global water mass reduction occurring during the air path of the droplet (Edling, 1985; Kincaid and Longley, 1989; James, 1996). The experimental tests, however, have clearly showed that aerial spray evaporation is a relevant cause of water sink (Lorenzini, 2002). Spray evaporation from a droplet has been attributed to air relative humidity or to water vapor concentration and or gradient in the air with respect to the droplet position (Edling, 1985; Thompson *et al*., 1993; Kinzer and Gunn, 1951; Kincaid and Longley, 1989). A study by Lorenzini (2002) reviewed recent scientific literature regarding experimental tests on sprinkler droplet evaporation. Among the studies reported, the most relevant include Zanon and Testezlaf (1995) and Zanon *et al*. (2000), who analyzed the problems of experimental techniques for automatic systems of water collection at ground level and the methods for measurement of the water collected in order to reduce experimental and wind drift. In the average meteorological conditions of Zaragoza (Spain), the seasonal average spray losses for the solid-set system would be 15.4 and 8.5% during day and night irrigations, respectively (Playan *et al*., 2005).

## MATERIALS AND METHODS

The studies described in this research were conducted on an oat-stubble field at the research farmland, located southeast Khuzestan Province of Iran at 49°42' 30 E and 30°50' N, during the period of June (2006) through February (2007). In order to obtain logic and reliable results 75 tests were carried out in different hour during day and night so, the correlations and diagrams would represent a wide range of hydraulic and climatic conditions. Water was supplied from a permanent irrigation system. The commercial (jaleh model 3) with two nozzles (7.32×3.32) impact sprinkler was located on the lateral. Riser allowed the sprinkler to be placed 6.562 ft above the catch can openings. The system was operated at three pressure levels of 345.1, 394.4 and 443.7 kPa. A total of 100 catch containers on a 9.8×9.8 grid system were located on both side of the lateral a round the sprinkler. Figure 1 shows an arrangement of rain gages for such a test. The area a round the sprinkler was divided into squares of equal area. A catch-can placed at the center of each square then represented the precipitation falling on that area and the catch-cans opening diameter was 10 and 15 cm height. The measurable parameters

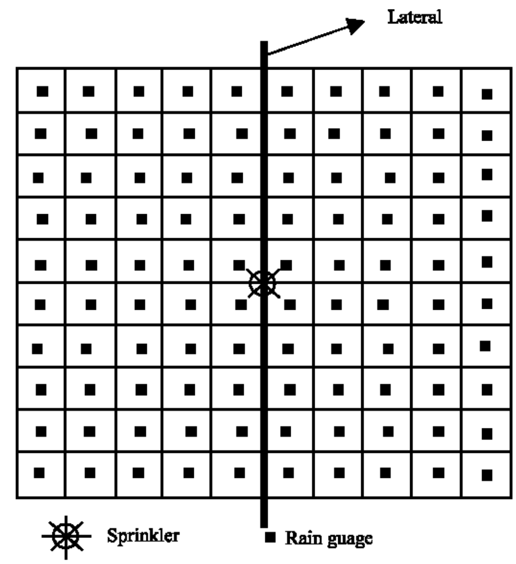


Fig. 1: Arrangement of rain gauges (catch-containers) a round the sprinkler

in this study included: temperature, relative moisture, wind velocity, operating pressure, flow discharge and volume of water from the sprinklers accumulated in the containers. Metrological parameters were measured by installing a 3-cup anemometer and dry and wet thermometers. The sprinkler's flow discharge was accurately determined by using a volume meter and a chronometer. Wind velocity and direction at 6.6 ft above ground were measured with a recording 3-cup anemometer and wind vane for a time period equal to the duration of a test, which was about 1 h. Dry and wet-bulb temperatures were measured with a sling psychrometer at 10 min intervals in the upwind direction during each test. A portable indicating bridge with a conductivity cell was used to measure the electrical conductivities of both the water supply and that in the catch-containers. Evaporation losses were determined from the relationship.

$$E = 100\,(EC_s - EC_1)/EC_1$$

where, E is the evaporation losses (%) and $EC_1$ and $EC_1$ are the electrical conductivities of the samples of the water in the catch-containers and of the supply water, respectively. Minimum working time of the sprinkler during each treatment was 1 h.

## RESULTS AND DISCUSSION

A total of 75 evaporation-loss tests were conducted and the results of the selected observations are given in Table 1. Evaporation losses ranged from 4.4% at a vapor

Table 1: Evaporation losses under various climatic and operating conditions

| No. of observations | Wind speed (mil $h^{-1}$) | Vapor pressure deficit (mbar) | Air temperature (°C) | Operating pressure (kPa) | Evaporation loss (%) |
|---|---|---|---|---|---|
| | 12.530 | 6.70 | 40.8 | 443.7 | 4.9 |
| 1 | 8.948 | 3.45 | 31.0 | 394.4 | 6.3 |
| 2 | 10.070 | 4.14 | 34.0 | 394.4 | 5.6 |
| 3 | 8.053 | 8.90 | 45.4 | 345.1 | 4.7 |
| 5 | 21.250 | 1.64 | 21.8 | 394.4 | 8.4 |
| 7 | 13.870 | 3.00 | 29.0 | 345.1 | 7.1 |
| 9 | 14.990 | 2.80 | 27.0 | 443.7 | 7.3 |
| 11 | 11.190 | 3.90 | 31.8 | 343.7 | 5.8 |
| 12 | 22.800 | 1.20 | 21.8 | 345.1 | 8.9 |
| 13 | 10.070 | 2.70 | 26.4 | 345.1 | 6.2 |
| 19 | 13.420 | 1.53 | 22.0 | 345.1 | 7.3 |
| 22 | 12.080 | 4.00 | 19.8 | 394.4 | 5.8 |
| 25 | 13.420 | 1.40 | 21.2 | 345.1 | 7.4 |
| 26 | 10.290 | 3.50 | 32.6 | 394.4 | 5.7 |
| 29 | 7.606 | 6.40 | 40.6 | 394.4 | 4.8 |
| 30 | 11.190 | 4.40 | 34.0 | 345.1 | 6.6 |
| 33 | 6.711 | 5.80 | 40.6 | 443.7 | 4.7 |
| 34 | 6.711 | 5.80 | 39.0 | 345.1 | 4.4 |
| 37 | 8.948 | 4.50 | 36.8 | 345.1 | 5.4 |
| 40 | 6.711 | 5.10 | 37.4 | 394.4 | 5.1 |
| 41 | 15.660 | 3.50 | 34.2 | 345.1 | 7.5 |
| 42 | 13.420 | 2.60 | 33.0 | 394.4 | 7.7 |
| 43 | 17.450 | 3.80 | 36.8 | 443.7 | 7.0 |
| 45 | 8.948 | 4.70 | 38.8 | 345.1 | 5.6 |
| 50 | 13.420 | 1.60 | 30.6 | 345.1 | 7.4 |
| 55 | 6.711 | 5.10 | 36.0 | 394.4 | 5.1 |
| 57 | 13.420 | 1.70 | 26.2 | 394.4 | 7.2 |
| 58 | 11.190 | 2.70 | 32.0 | 443.7 | 6.3 |
| 59 | 15.660 | 1.30 | 29.0 | 345.1 | 7.8 |
| 61 | 8.948 | 4.50 | 38.0 | 443.7 | 5.8 |
| 62 | 11.190 | 6.30 | 42.6 | 443.7 | 4.4 |
| 64 | 6.711 | 8.14 | 45.0 | 345.1 | 4.7 |
| 66 | 22.370 | 0.70 | 31.0 | 345.1 | 8.7 |
| 68 | 13.420 | 2.40 | 35.2 | 443.7 | 7.4 |
| 70 | 15.660 | 0.92 | 32.4 | 394.4 | 7.8 |
| 71 | 6.711 | 5.10 | 40.0 | 394.4 | 5.1 |
| 75 | 11.190 | 4.20 | 24.4 | 443.7 | 6.7 |

pressure deficit of 5.8 mbar and wind velocity of 6.711 mil $h^{-1}$ to 8.9% at a vapor pressure deficit of 1.2 mbar and wind velocity of 22.82 mil $h^{-1}$ multiple regression analysis of the data was performed by using a non-linear calculating technique and the following expression for predicting the evaporation losses from sprinkler sprays was obtained:

$$E = 4.4\exp(0.66u)(e_s - e_0)^{-0.125} T_a^{-0.115} P^{0.381} \quad r = 0.837 \tag{1}$$

where, E is the evaporation losses expressed as the percentage of the total volume discharged by sprinklers; u is the wind velocity at 2 m (mil $h^{-1}$); ($e_s$-$e_0$) is the vapor pressure deficit, in which $e_s$ and $e_0$ are the saturation vapor pressure and the actual vapor pressure of the air (mbar); $T_a$ is the air temperature (°C) and P is the operating pressure (kPa).

When the air temperature factor is omitted, then the prediction equation becomes:

$$E = 4.37\exp(0.047u)(e_s - e_0)^{-0.13} P^{0.361} \quad r = 0.832 \tag{2}$$

Since the air temperature term is indirectly included in the vapor pressure deficit term, the resulting multiple correlation coefficient remains unchanged.

When the operating pressure factor is deleted, the resulting equation is given by:

$$E = 4.375\exp(0.106u)(e_s - e_0)^{-0.092} T_a^{-0.102} \quad r = 0.828 \tag{3}$$

Considering only the wind velocity and vapor pressure deficit in the analysis, the equation becomes:

$$E = 4.337\exp(0.077u)(e_s - e_0)^{-0.098} \quad r = 0.826 \tag{4}$$

The relationship between the evaporation loss and wind velocity alone, shown in Fig. 2, is given by:

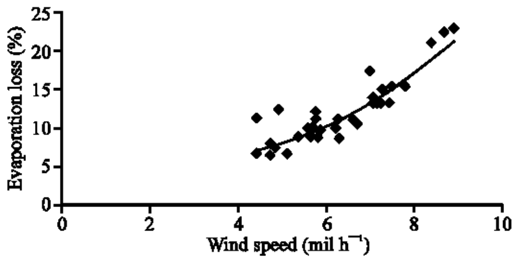


Fig. 2: Relationship between the evaporation losses and wind velocity

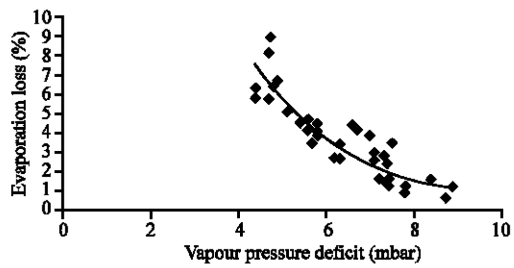


Fig. 3: Relationship between evaporation losses and vapor pressure deficit

$$E = 3.92\exp(0.0878u) \qquad (5)$$
$$r = 0.802$$

The relationship between the evaporation loss and vapor pressure deficit, shown in Fig. 3, is:

$$E = 8.756\exp(-0.091)(e_s - e_0) \qquad (6)$$
$$r = 0.821$$

The results of the multiple regression analysis of the data indicate the wind velocity and vapor pressure deficit are the predominant factors affecting the evaporation from the sprinkler sprays. The operation losses, for the pressure levels used in this study. Since, the two nozzle sizes had very similar flow characteristics at each pressure level, the test were considered as replications. Therefore no conclusions can be drawn with respect to the nozzle size.

The result of this study is closely in support with Yazar (1984) and Frost and Schwalen (1955). Wind not only causes spray droplets to be carried beyond the sprayed field but also distorts the distribution pattern of the sprinklers; which in turn results in a very uneven application of water over the field. Combined losses from a sprinkler system for a given set of operation conditions have been estimated by using the results obtained from the experiments. Combined losses ranged from 4.4 to 8.9% of the applied water.

## ACKNOWLEDGMENT

The authors should thank the Islamic Azad University of Sciences and Research Branch of Ahvaz and Research and Standards Office for Irrigation and Drainage Networks of KWPA for their financial support and assistance.

## REFERENCES

Christiansen, J.E., 1942. Irrigation by sprinkling. Calif. Agric. Exp. Stn. Bull. Bull., pp: 670.

Edling, P.J., 1985. Kinetic energy, evaporation and wind drift of droplets from low-pressure irrigation nozzles. Trans. ASAE, 28: 1543-1550.

Frost, K.B. and H.C. Schwalen, 1955. Sprinkler evaporation losses. Agric. Eng., 36: 526-528.

Hermsmeier, F.L., 1973. Evaporation during sprinkler application in a desert dim at ASAE. Pap., pp: 73-216.

James, L.G., 1996. Principles of Farm Irrigation System Design. 1st Edn., Wiley, London, ISBN-10: 0894648020.

Kincaid, D.C. and T.S. Longley, 1989. A water droplet evaporation and temperature model. Trans. ASAE, 32: 457-463.

Kinzer, G.D. and R. Gunn, 1951. The evaporation, temperature and thermal relaxation time of freely falling water drops. J. Metrol., 8: 71-83.

Lorenzini, G., 2002. Air temperature effect on spray evaporation in sprinkler irrigation. Irrigat. Drainage, 51: 301-309.

Playan, E., R. Salvador, L.M. Faci, N. Zapata and A. Mal1I'neZ-Cob *et al*., 2005. Day and night wind drift and evaporation losses in sprinkler solid-sets and moving laterals. Agric. Water Manage., 76: 139-159.

Thompson, A.L., G.R. Gilley and J.M. Norman, 1993. A sprinkler water droplet evaporation and plant canopy model: II. Model application. Trans. ASAE, 36: 743-750.

Yazar, A., 1984. Evaporation and drift losses from sprinkler irrigation systems under various operating conditions. Agric. Water Manage., 8: 439-449.

Zanon, E.R. and F. Testezlaf, 1995. Use of load cells in radius layout sprinkler uniformity tests. Proceedings XXIV Brazilian Congress of Agriculture Engineers, 1995 M.G. Brazilian Society of Agricultural Engineering, Brasilia, pp: 254-263.

Zanon, E.R., R. Testezlaf and E.J. Matsura, 2000. A data acquisition system for sprinkler uniformity testing. Applied Eng. Agric., 16: 123-127.