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The Effect of Climat Variations on Water Losses During Sprinkling

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□ ABSTRACT □

Reducing the water losses from irrigation system is important for achieving water conservation. The effect of monthly and daily climate variations on water losses due to evaporation and wind drift during sprinkling have been investigated experimentally. Three types of sprinklers were used in this research: Al-khirat, Andlian and Rainbird40. For Al-khirat sprinkler and during irrigation season, the maximum water losses occur in August (50%), while the minimum water losses occur in May (27%). For July, the measurements showed that the water losses during daytimes were 2.5 to 3.4 times the water losses during nighttimes. The comparison between experimental and Frost and Schwalen nomograph results showed that the experimental results were always higher than the Frost and Schwalen results.

Key words: sprinkling irrigation, spry evaporation losses, wind drift losses.

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تأثير التغيرات المناخية على الفواقد المائية أثناء الرش

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□ ملخّص □

إن تخفيض الضياعات المائية في أنظمة الري له أهمية كبيرة في المحافظة على المياه. لقد تم في هذا البحث تحديد تأثير التغيرات المناخية اليومية والشهرية على الضياعات المائية نتيجة للتبخر وجرف الهواء أثناء الرش بشكل تجريبي. واستخدام لذلك ثلاثة أنواع من المرشات هي مرش الخيرات ومرش أندليان ومرش Rainbird40 . وإن دراسة الضياعات بالتبخر وجرف الهواء خلال موسم السقاية لدى استخدام مرش الخيرات أظهرت أن أكبر الضياعات حدثت خلال شهر آب 50% وأقل ضياعات حدثت خلال شهر أيار 27%. كما أن دراسة تغير الضياعات في اليوم خلال شهر تموز أظهرت أن الضياعات من الرش أثناء النهار تراوحت بين 2.5 و 3.0 مرات قيمة الضياعات أثناء الرش في ساعات الليل. وبمقارنة الضياعات المحسوبة بواسطة مخطط فروست وسكوالين مع القيم المقاسة لها، تبين أن الضياعات المقاسة أكبر بشكل واضح من الضياعات المستنتجة باستخدام هذا المخطط.

الكلمات المفتاحية: الري بالرش، ضياعات التبخر من الرش، ضياعات جرف الهواء من الرش.

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Introduction:

Agriculture is the largest consumptive user of water throughout the world. The productivity of irrigated agriculture is significantly higher than the productivity of rain fed agriculture, especially in arid and semi-arid regions. In many countries, the sprinkler irrigation system is one of the popular methods for achieving high application efficiencies and conservation water. The water losses in sprinkler ir163rigation systems are about 5% - 40%, so the efficiency of this method is about 60% to 95% [1, 11]. In a sprinkler irrigation system, very little water is lost in the conveyance system up to the sprinkler nozzle. The major portion of the loss in the field occurs from the time water leaves the sprinkler nozzle until it reaches the root zone. Losses at the field level include evaporation from spray droplets that are traveling through the air, the wind drift losses, the portion intercepted by the crop canopy, and water deep percolating below the root zone [10].

The dominated climate in the region, the type of sprinkler, the time available for evaporation (the time from the moment water droplet leaves the nozzle until reaches the ground or plant surface) and the total surface area of the water droplets affect on the evaporation losses during sprinkling. The relative humidity, which ranges from near 0 to 100%, has a significant effect on evaporation losses during sprinkling. The evaporation will occur more rapidly when the air is dry than when it is moist. The evaporation occurs from the surface of the water droplets, so the evaporation losses depend on the total surface area of the water droplets. For this reason, evaporation rate increases as droplet size decreases if other factors remain constant [13]. Wind drift losses occur when wind carries water droplets away from the irrigated area. Carried droplets may either evaporate or may fall outside the irrigated area. Wind drift losses increase as wind speeds increase and as droplet sizes decrease. At high wind speeds, large droplets can be drifted by the wind and droplets can be transported to long distances [13].

Objectives of the Study:

This research aims to determine the water losses due to evaporation and wind drift losses during sprinkling, in the climate conditions of studied area. The objectives of the present study can be summarized as following:

1- Determining the effect of monthly climate variations on evaporation and wind drift losses during sprinkling in the irrigation season.

2- Studying the effect of daily climate variations on evaporation and wind drift losses during sprinkling.

Materials and Methods:

The experiments were conducted in the experimental irrigation filed at Civil Engineering Faculty-Al Baath University, during deferent periods from the irrigation season. For executed the experiments, the used equipments are:

- Digital weather station to register temperature, air humidity and wind speed;
- Water tank with $12m^3$ volume;
- Centrifugal pump provides a required discharge and pressure for the studied sprinklers;
- A net pipes with connections and valves were used to control the discharge and pressure;
- An equipments to measure the sprinkler discharge;
- Plastic white catch cans were used with 106.60 cm^2 cross section area;

- Three different types of sprinklers were used in this study: Al-khirat, Andlian and Rainbird. The suitable operating pressure (H_{sut}), the main nozzle diameter (d_1), the secondary nozzle diameter (d_2), radius of the sprinkling (R) and the total discharge of the studied sprinklers (Q), are shown in Table (1) [18].

The studied sprinklers have been worked at the suitable operating pressure for each one. Discharge of each sprinkler has been measured by measuring the volume of water collected and the corresponding time.

Table (1) The technical and working specifications of the studied sprinklers

Type of sprinkler	Al-khirat	Andlian	Rainbird
H_{sut} (m)	32	28	39
d_1 (mm)	3.51	4.08	3.54
d_2 (mm)	2.59	2.65	-
R (m)	12.7	13.5	13.0
Q (m^3/hr)	1.070	1.370	0.956

For measuring the water that arrives to the soil surface, four hundred catch cans have been distributed around the studied sprinkler in square grid (1.5m x1.5m). The water collected in each catch can is measured.

For the purpose of this study, the evaporation and wind drift losses during sprinkling were defined as the amount of water that lost while the water droplets travel between the sprinkler nozzle and soil surface, calculated as a percentage of sprinkler discharge. The loss of water by evaporation from the catch cans during the duration of the sample collection period can be neglected [7].

Literature Review:

There are many studies related to the evaporation and wind drift losses from sprinkler irrigation. Till measured the spray evaporation losses using the change in concentration of chloride ions in the irrigation water traveling from the sprinkler nozzle to the ground [15]. Frost and Schwalen developed a nomograph that enables to estimate the percentage of evaporation loss during sprinkler irrigation as a function of sprinkler characteristics, operating pressure, and climate factors [4]. They concluded that evaporation loss could be accurately estimated using three climate factors: air temperature, relative humidity, and wind speed. They found spray losses as high as 45% under extreme conditions of bright sunlight, high temperatures, and low humidity dominate in Arizona. Also, they concluded that evaporation losses increased 25% when operating pressure at nozzle increased 25%. They also noted that smaller nozzle diameters tended to break up the droplets leading to greater evaporation losses. Myers *et al*. conducted wind tunnel tests of sprinkler evaporation loss for typical Florida climate conditions [9]. They stated it is unlikely that evaporation from water droplets in transit from the sprinkler to the ground or plant surface could represent more than 5 percent of the water applied by typical sprinkler irrigation systems under Florida climate conditions. Seginer found strong correlations between sprinkler evaporation loss and both solar radiation and air temperature, and weak correlations with relative humidity and wind speed [12]. He concluded that evaporation loss due to wind drift was negligible for the 3 to 4 m/h wind speed conditions of his study. Hermsmeier used EC method and found that evaporation from sprinklers could range from 0 to 50% over short periods [5]. He also noted that evaporation during daytime hours is 3 to 4 times the evaporation during nighttime hours during July and August in the Imperial Valley, California. The air temperature and the rate of application were found to be better factors for estimating sprinkler evaporation than wind speed or relative humidity. Yazar reported the losses to be between 1.5 and 16.8% of the total sprinkled volume on tests performed in Nebraska [17]. He also found that wind velocity and vapor pressure deficit were the most significant factors affecting the losses. Kohl and DeBoer observed that for low pressure spray type agricultural sprinklers, the geometry of the spray plate surface influenced more than the nozzle size and operating pressure on drop size and distribution of water [6]. They also found that smooth spray plates produced smaller droplets compared to coarse-grooved spray plates. Edling showed a rapid reduction of evaporation and drift losses when the drop diameter increases from 0.3 to 1.0mm, as well as a high dependency of losses on wind speed and riser height in the case of 0.3mm drop diameter[3]. This dependency is much less important for drop diameters over 0.6mm. Vories and Von Bernuth found that a sprinkler of a given nozzle size, trajectory angle, and operating pressure produced a set range of drop sizes [16]. Chaya and Hills reported that for a given nozzle size, the droplet size was found to be inversely proportional to the operating pressure [2]. In addition, the droplet diameter was also found to be proportional to the Reynolds number. Tarjuelo *et al*. have realized an experimental study on water losses in sprinkler irrigation due to evaporation and wind drift, without examining closely the effect of the surrounding air temperature [14]. Mclean *et al* used the electrical conductivity (EC) method to determine the above canopy spray evaporation loss (ACSEL) from different types of sprinkler irrigation systems calculated at different distances from the sprinkler nozzles [8]. In this method, the change in solute concentration and consequent change in EC as the water droplets travel through the air to the cans was used to calculate the volume lost by evaporation. By measuring the EC of the source water and the EC of the water caught in individual collectors positioned just above the crop canopy, the spray evaporation loss was calculated using:

$$Loss(\%) = \frac{EC_c - EC_s}{EC_c} \times 100$$

Where:

EC_C - electrical conductivity of water in the collector, and

EC_S - electrical conductivity of the source water.

Lorenzini studied the influence of the environmental air temperature, holding all the other variables constant to minimize experimental error. He found the evaporation ranged from 4.15 to 7.73% as the air temperature varied from 21.0 to 27.0^{o}C [7].

The Frost and Schwalen nomograph can be used to estimate evaporation loss for specific climate and operating conditions. This nomograph allows estimating the evaporation loss depending on air temperature, relative humidity, main nozzle diameter, operating pressure and wind speed [4], as shown in figure (1).

Results and Discussion:

In this research, the experiments have been performed to determine the water losses during sprinkling. The experiments have been executed between the beginning of autumn (2006) and the end of summer (2008), during different period from each year. Generally, the irrigation season begins from May to October, so the experiments have been focused during this period.

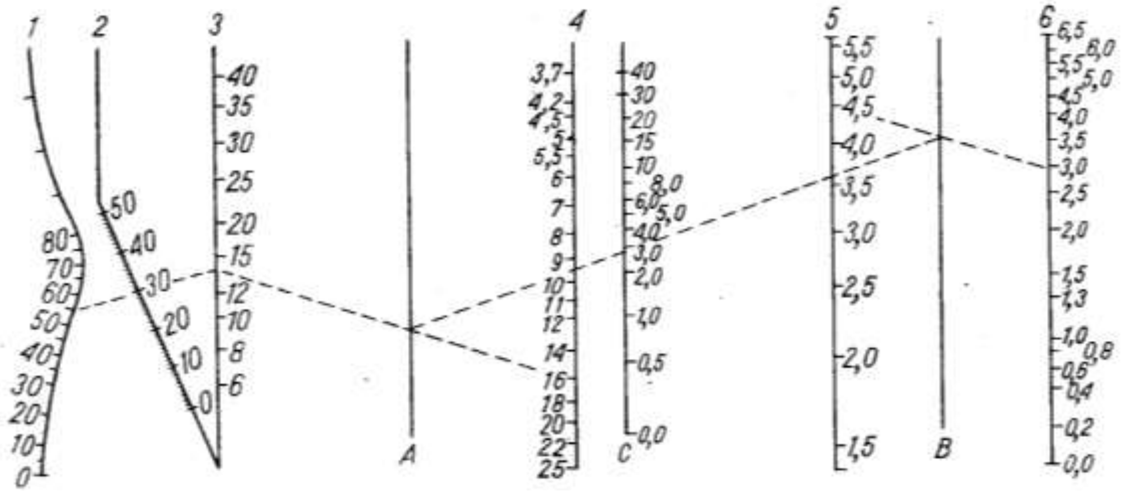


Fig. (1) Frost and Schwalen nomograph to estimate the evaporation loss: 1- relative humidity (%), 2- air temperature (^oC), 3- vapor-pressure deficit (mm), 4- main nozzle diameter (mm), 5- nozzle pressure (at), 6- wind speed (m/sec.), A, B- pivot lines, C- evaporation loss (%).

Depending on Homs Meteorological Station, the annual climate variations have been observed, as shown in Table (2). The dry mean temperature was between 6.9 ^oC in January and 26 ^oC in August. The mean relative humidity was between 55.2% in Jun and 79.6% in December, while the minimum relative humidity was between 13.1% and 34.8% in September and December, respectively. The daily mean wind speed was between 1.6 m/sec. and 5.4 m/sec. in November and July, respectively.

Table (2) the average of climate elements in Homs Meteorological Station during the period between 1980 and 2000.

Month	RHmin (%)	RH (%)	T (^oC)	U (m/sec)
Jan	30.4	78.9	6.9	2.2
Feb	28.1	73.7	7.9	2.8
Mar	21.5	69.3	11.0	3.2
Apr	17.8	64.2	15.5	3.5
May	13.8	57.8	20.3	3.7
Jun	14.8	55.2	24.2	4.6
Jul	16.3	57.9	26.5	5.4
Aug	18.1	59.7	26.8	4.8
Sep	13.1	57.6	24.7	3.3
Oct	14.1	59.3	20.1	2.0
Nov	22.2	69.3	12.8	1.6
Dec	34.8	79.6	8.1	1.8

For each experiment, the temperature, relative humidity and wind speed are directly registered. The evaporation and wind drift during sprinkling have been estimated as the difference between the water discharged by sprinklers and the water collected by catch cans (WL_e %).

Table (3) shows the values of climate variables and the water losses during sprinkling for different period from the year for Al-hkirat sprinkler. The water losses during sprinkling increases from 27% in May to 50% in August as percentage of discharge for Al-khirat sprinkler according to the suitable operating pressure, then decreases in September to 47%, as shown in Figure (2).

Table (3) values of WL_e% and the climatic elements for different period from the year for Al-hkirat sprinkler.

U (m/s)	T (^oC)	RH (%)	WL_e (%)
0	16.3	39.0	22.1
0.78	29.3	32.4	30.82
1.67	27.8	39.3	32.77
1.87	27.2	39.4	48.43
2.31	28.8	54.9	47.50
2.43	32.1	35.5	51.93
2.58	17.65	60.5	17.39
2.61	27.75	47.5	43.85
2.78	26.90	51.75	48.06
3.00	20.60	54.60	22.77
6.48	28.60	32.90	45.77

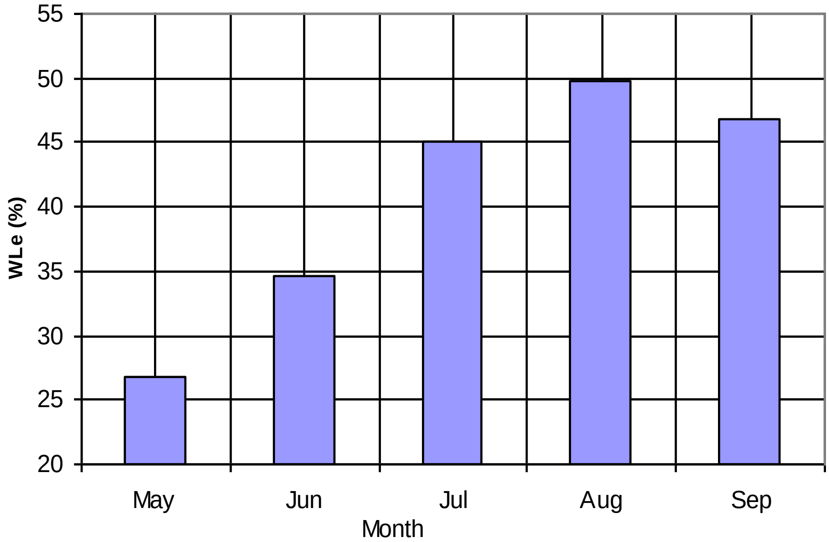


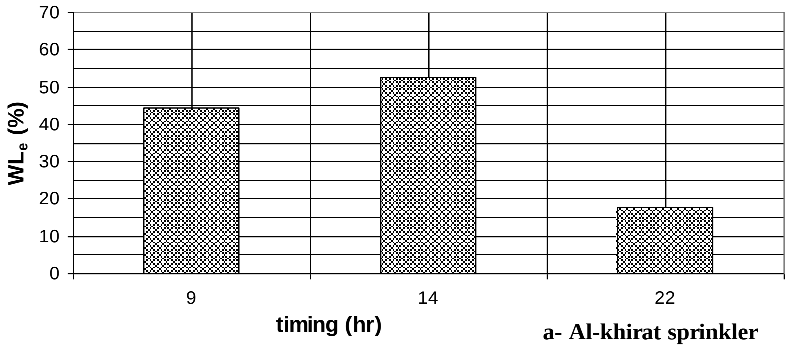
Fig. (2) Values of WL_e during irrigation season for Al-khirat sprinkler.

The effect of daily climate variations on evaporation and wind drift losses has been studied experimentally. Three different types of sprinklers were used in this study, as shown in Table (1). The experiments were conducted during July 2008. Also, the experiments were executed during three periods. The first period is from 8.00 to 11.00 o'clock, the second period is from 12.00 to 15.00 o'clock and the third period is from 21.00 to 24.00 o'clock. Table (4) shows that the effect of daily climate variations on evaporation and wind drift losses during sprinkling for different sprinklers.

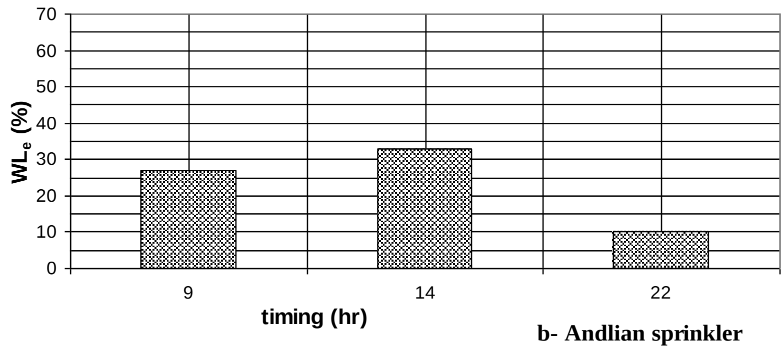
Figures (3-a), (3-b) and (3-c) show the variations of the evaporation and wind drift losses during day, in July, for Al-khirat, Andlian and Rainbird, respectively.

Table (4) effect of daily climate variations on water losses during sprinkling for different sprinklers.

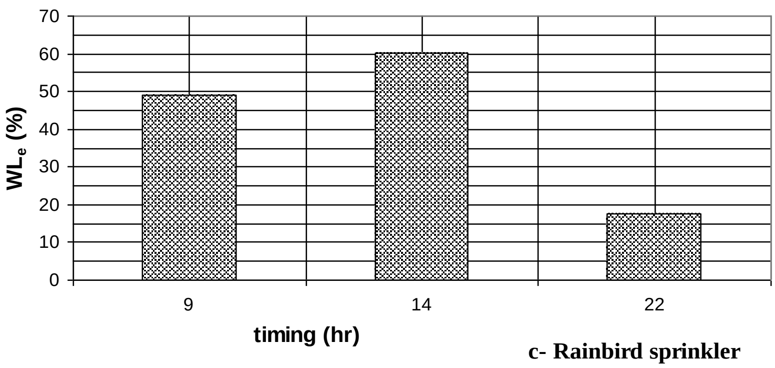
Sprinklers	Timing	U (m/s)	T(^{o} C)	RH(%)	H(m)	Q_n(m^3/hr)	WL_e(%)
Al-khirat	I	2.70	27.75	39.50	32	1.07	44.27
	II	3.03	29.00	35.50	32	1.07	52.46
	III	2.42	21.15	50.00	32	1.07	17.73
Andlian	I	2.34	23.5	41.50	28	1.37	26.83
	II	2.84	28.00	34.25	28	1.37	33.01
	III	3.29	21.00	56.50	28	1.37	9.99
Rainbird	I	2.27	25.75	45.25	39	0.956	48.90
	II	2.01	30.25	31.50	39	0.956	60.35
	III	2.36	21.50	65.00	39	0.956	17.61



a- Al-khirat sprinkler



b- Andlian sprinkler



c- Rainbird sprinkler

Fig. (3) Variation of the value of WLe during day for July 2008.

From the figure (3), it is clear that the minimum value of the water losses during sprinkling (WL_e) occurs at night (third period) is 9.99%, 17.73% and 17.61% for Andlian, Al-khirat and Rainbird sprinklers, respectively. At morning (first period), value of WLe is 26.83%, 44.27% and 48.90% for Andlian, Al-khirat and Rainbird sprinklers , respectively. While, value of WLe, at afternoon (second period), equals 33.01%, 52.46% and 60.35% for Andlian, Al-khirat and Rainbird sprinklers, respectively. From the previous analysis, the evaporation and wind drift losses during sprinkling are the smallest for Andlian sprinkler then Al-khirat sprinkler and then Rainbird sprinkler. Also, from the figure (3), can be noticed that the water losses from Andlian during morning are 2.7 times the water losses during night. Also, the water losses during afternoon are 3.3 times the water losses during night. For Al-khirat sprinkler, the water losses during morning are 2.5 times the water losses during night. Also, the water losses during afternoon are 3.0 times the water losses during night. While, for Rainbird sprinkler the water losses during morning are 2.8 times the water losses during night. Also, the water losses during afternoon are 3.4 times the water losses during night

Conclusions:

Determining the water loss for irrigation methods is very important to choose the suitable method, especially in the arid and semi-arid regions. The main conclusions of the present study can be summarized in the following points:

1- For Al-Khirat sprinkler, the water losses during sprinkling season increase from 27% in May to 50% in August as percentage of sprinkler discharge, then decreases in September to 47%.

2- The water losses due to evaporation and wind drift represent great percentage. The maximum water losses occur at daytime was about 33 %, 52% and 60% for Andlian, Al-khirat and Rainbird sprinklers, respectively. While, the minimum water losses occurs at nighttime were about 10%, 18% and 18% for Andlian, Al-khirat and Rainbird sprinklers, respectively.

3- During July 2008, the water losses during sprinkling from Andlian sprinkler at daytime hours were 2.7 to 3.3 times the water losses during nighttime hours. Also, it was 2.5 to 3.0 for Al-khirat sprinkler. For Rainbird sprinkler, it was 2.8 to 3.4. Generally, it is recommended that, the sprinkling during nighttimes decreases the water losses with great percentage.

4- For the studied sprinklers, the smallest water losses were for Andlian then Al-khirat and then Rainbird. For this reason, it is preferred that to consider the water losses from sprinkler as a factor, we have to select the sprinkler as well as other technical and operating factors, like sprinkler intensity and volume of sprinkling droplets.

5- This research Confirms the important of scientific research results in using the sprinkling irrigation.

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