Original scientific paper
https://doi.org/10.31784/zvr.13.1.14
Received: 10. 3. 2024.
Accepted: 23. 10. 2024.

THE EVALUATION OF DEFICIT IRRIGATION EFFECT ON URBAN LANDSCAPE PLANTS IN MASHHAD (ROSE AND TREVEN)

Jafar Hashempour
PhD, Assistant Professor, Department of Water Science and Engineering, Ferdowsi University of Mashhad, Iran; email: jafar.hashempour@mail.um.ac.ir

Sara Dadar
PhD student, Department of Water Science and Engineering, Ferdowsi University of Mashhad, Iran; email: sara.dadar@mail.um.ac.ir

Bojan Đurin
PhD, Associate Professor, Department of Civil Engineering, University North, 42000 Varaždin, Croatia; email: bdjurin@unin.hr

Marko Šrajbek
PhD, Assistant Professor, Department of Civil Engineering, University North, 42000 Varaždin, Croatia; email: msrajbek@unin.hr

Domagoj Nakić
PhD, Assistant Professor, Faculty of Civil Engineering, University of Zagreb, 10000 Zagreb, Croatia; Department of Civil Engineering, University North, 42000 Varaždin, Croatia;
email: domagoj.nakic@grad.unizg.hr; dnakic@unin.hr

ABSTRACT

This study was carried out in Mashhad to analyze the effect of deficit irrigation on landscape plants and determine accurate evapotranspiration values. The study was done using statistical factorial analysis in completely randomized blocks with three repetitions. Rose and Treven were irrigated in different amounts corresponding to the four levels of potential evapotranspiration: 50, 60, 80, and 100%, and the parameters of plant height, stem diameter, and the number of leaves and flowers were evaluated. The result showed that different irrigation levels had a meaningful effect on plant parameters, and the best growth was obtained at an irrigation rate of 80% of potential evapotranspiration.

Keywords: *water requirement, landscape, Rose, Treven, plant coefficient, irrigation deficit*

1. INTRODUCTION

Optimum exploitation and proper management of existing water resources, development of sustainable green spaces with lower water demand, and optimization and rational management of water consumption by developing irrigation systems with high application efficiency and distribution, including appropriate methods to reduce the effects of drought and dealing with water shortages should be high on the agenda of the local governments. To tackle this issue properly, the following points should be considered:

- Using the pattern of green spaces according to the conditions of water resources,
- Use of irrigation methods with high efficiency, and
- Use of non-conventional water resources for environmental issues.

All of the above are important components of the optimal use of water resources. Still, the point often forgotten is the optimal design and accurate determination of the amount of water consumption, which is considered the water requirement of the cultivation pattern. Due to different methods and formulas for determining the water requirement and the lack of a single guideline following the environmental and plant conditions in the water requirement section of the green areas, there seem to be many differences between the studies by different authors/consultants. In the case of a calculation higher than the requirement, it leads to increased project costs and non-rational use of water resources. At the same time, if it is calculated less than the need, it will lead to less irrigation and decrease the desirability of the green space (Jam Kasht, 2010).

Smeal et al. (2001) examined grass evaporation and transpiration in Mexico between 1998 and 2000 using the Samani formula. They ranged the crop coefficient (K_c values) between 0.3 and 0.72 for cold-season grass and between 0.15 and 0.6 for warm-season grass. Jia et al. (2009) obtained the crop coefficient value for the South Florida green space plant using the Hargreaves formula between 0.7 and 0.99. Kenna (2006), in research on the water requirement of green space plants, concluded that warm-season plants consume between 0.22 and 0.35 and cold-season plants consume between 0.12 and 0.5 inches of water per day. Costello et al. (1999) classified 2,200 different types of green space plants in four irrigation groups over 30 years, such that high-consumption plants need water between 70 and 90% of evaporation and transpiration potential, plants with medium consumption require 40 to 60%, plants with low consumption 10 to 30% and very low consumption plants consume less than 10%. They also presented the density coefficient between 0.5 and 0.9 for plants with low coverage and between 1.1 and 1.3 for plants with proper coverage (Costello et al., 1999). Pittenger et al. (2004) investigated the growth of common green space plants with low irrigation and showed that water affected the cover growth and that the Kc value of denser plants is lower. Hashemi et al. (2009) investigated the water requirement of the dominant crops in the green space. The average crop coefficient of the sparrow's tongue tree for the whole period was 0.48; the maximum was 0.77 in August, and the minimum was 0.2 in April. The average crop coefficient of the silver cypress tree for the whole period was 0.43; the maximum was 0.58 in July and August, and the minimum was 0.3 in April. Sharifan et al. (2007) evaluated reference evaporation and transpiration using the experimental data, Penman-Monteith-FAO method, Hargreaves-Samani method, and Blaney-Cridel method in three data situations. They obtained the correlation equation of evaporation and transpiration. They showed that, with the increase in probability level, the difference in ET_c value calculated by using the Hargreaves-Samani method compared with the standard method is small, and the Jensen-Heise method shows an increasing trend (Sharifan et al., 2007).

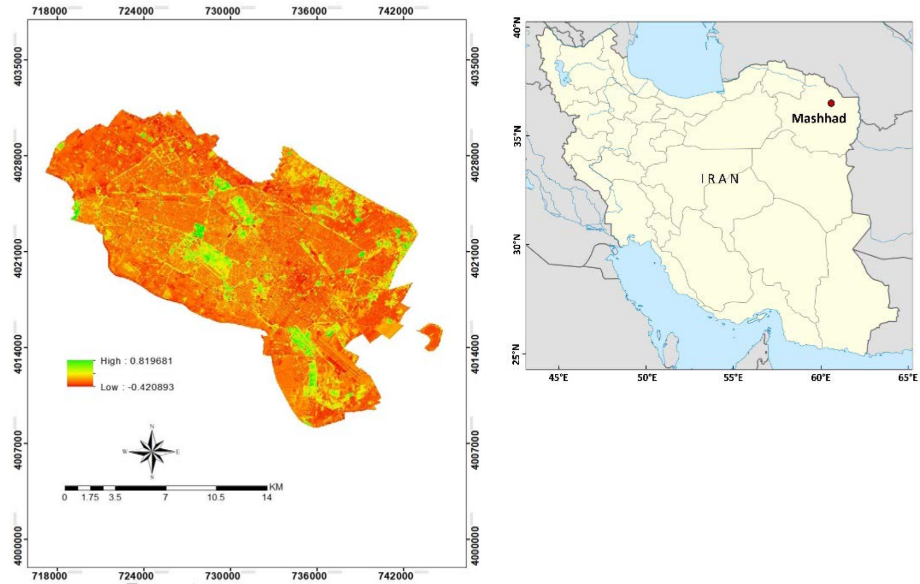
With cultural education about irrigation, it is possible to reduce water consumption. Rational irrigation is when ET_c is measured for plant growth. Huang (2006), in a project, showed that water stress affects the amount of evaporation and transpiration, the growth and appearance quality of the plant, and the values of K_c during water stress have special conditions that can be used to determine the usable water of tropical plants and cold plants used it, the rate of transpiration is usually higher in tropical plants. Alizadeh (2009) measured the evaporation and transpiration of green space plants directly from the lysimeter. The need for more grass irrigation has been estimated in urban plants, but this work has not been done for different types of green space plants.

Saeidi Nia et al. (2019) estimated evapotranspiration and the crop coefficient for two species, Chamomile and Cumin, using a lysimeter. The evapotranspiration was estimated to be 610.3 mm for Chamomile and 416.4 mm for Cumin.

K_c indicates variability based on specific crop characteristics influenced by cultivation and water management methods (Kang et al., 2003; Paço et al., 2012; Suleiman et al., 2013). To improve location-specific exactness, K_c requires calibration to adjust local crop varieties, cultural patterns, and weather variations (Pereira et al., 2015). Using specific coefficients becomes important for non-standard, stressed conditions, and evaluating crop and environmental characteristics (Howell et al., 2015; Muniandy et al., 2016; Lv et al., 2018). Similarly, *Kc* has been expanded to natural vegetation for hydrologic purposes, such as sparse brush vegetation in African highlands, where Kc varies with the leaf area index (LAI) or the effective ground cover (Descheemaeker et al., 2011). Regardless, its availability for natural vegetation is limited due to variations in density, vegetation health, and water availability. The seasonal performance of *Kc* is notable, excelling in mid-season but becoming less effective during harvest (Wang et al., 2018). Canopy size, ground shadowing, and plant age are additional relevant factors. While the crop coefficient approach performs well under well-watered conditions with nearly full vegetation cover (Pereira et al., 2015), it may overestimate actual evapotranspiration in semi-arid regions (Er-Raki et al., 2010).

Irrigation of green spaces increases significantly in the summer months, and about 40 to 60 percent of urban water consumption is related to these months. Tsirogiannis (2010), using GIS and research on water and soil parameters and coefficients of green space, showed that irrigation planning using GIS saves about 36% in water consumption of green space plants. According to the above cases, accurately determining water needs can be considered one of the most important goals of controlling water resources and their optimal use. This research aims to study the water requirement of two plant species, Rose and Treven, in the green space in Mashhad, Easting 726698.66 m E and Northing 4020805.33 m N (Figure 1). A red flower or rose (in Persian: hundred leaves) is a plant that belongs to the rose family (Figure 2a). Trevens are green fences for protection and fences or walls in urban spaces (Figure 2b).

Figure 1. Geographical position of the city of Mashhad in Iran with landscape and green space distribution map of Mashhad



Source: Sabouri et al., 2020

Figure 2. Rose and Treven plants in the city of Mashhad

(a) Rose (b) Treven

Source: Authors

2. MATERIAL AND METHODS

This research was carried out on two types of plants that are mostly used in urban green space to cover the crop of green belts, roads, and parks to obtain the crop coefficient of urban green space plants in Mashhad. Meteorological information for Mashhad was used to calculate potential evaporation and transpiration and the reference plant. The experimental site used was selected inside the city. Nine plants were selected from each species and transferred to the experimental environment. This research was done as a factorial in randomized complete blocks with three replications. The experimental treatments include two plant species, Rose and Treven, at four irrigation water supply levels, equivalent to 50, 60, 80, and 100% of reference evaporation and transpiration, respectively (Figure 3). A comparison of means was made based on Duncan's test, and all statistical calculations needed in this project were done using *MSTAT-C* software.

When solar radiation, relative humidity, and wind speed data are missing, they should be estimated using the procedures presented in this section. As an alternative, ET_0 can be estimated using the Hargreaves ET_0 equation. Hargreaves and Samani developed the method by using the evaporation and transpiration of the reference plant to estimate ET_0 using only air temperature data (FAO-56). This equation is presented as follows:

$$ET_O = 0.0162K_t * R_a * TD^{0.5}(T + 17.8)$$

$$K_t = 0.075(S/TD)^{0.5}$$

ET_0 – evaporation and transpiration of grass reference plant (mm d^{-1})
S – percentage of sunshine hours
TD – the average difference between the maximum and minimum daily temperature
R_a – extraterrestrial radiation in millimeters of water (MJ m^{-2} d^{-1})
T – average daily temperature (°C)

In the above equation, instead of 0.0162 (K_t), a constant value of 0.0023 can be applied. The average daily temperature according to the maximum and minimum temperature of the local weather station during the growth period is given in Figure 4. As it can be seen, in the Hargreaves-Samani method, it is necessary to calculate the percentage of sunlight *S*, which is equal to:

$$S = n/N * 100,$$

where *n* is the actual number of hours of sunshine in the desired period, and *N* is the maximum number of hours of sunshine in that area, depending on the geographical latitude (Alizadeh, 2010). To determine the evaporation and transpiration potential of the plant, in addition to having the reference evaporation and transpiration, the crop coefficient of the cultivation pattern should be determined, and the amount of evaporation and transpiration potential should be calculated using the following relationship.

$$ET_L = ET_O * K_L$$

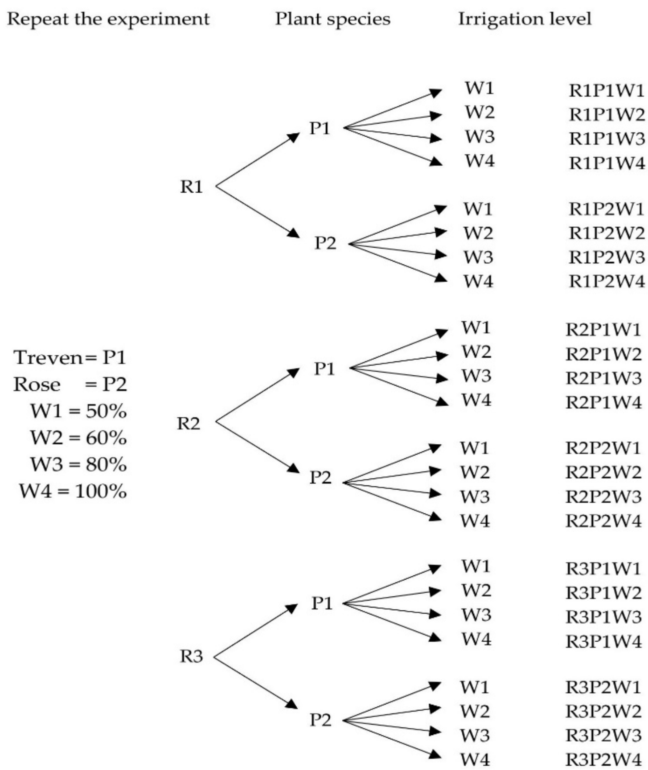
ET_L – evaporation and transpiration of green space plants (mm d^{-1})
K_L – crop coefficient of green space

Crop coefficient K_L shows the effects of crop type, crop density, climatic characteristics, and other factors affecting ET_L. The water consumed at each irrigation level was determined based on evaporation, transpiration calculations, and water demand. It was applied to tested plant species. The reference plant in Mashhad served as the benchmark for determining irrigation levels, with evaporation and transpiration values as the basis set at 100%. Three lower irrigation levels were also established for the experiments at 20%, 40%, and 50% of the reference amount. Therefore, the irrigation levels applied in this study correspond to 100%, 80%, 60%, and 50% of the evaporation and transpiration levels of the reference plant. This approach enhances the reliability of our experimental setup. The daily water requirement of each level was calculated using the following formula:

$$V = S * ET_0$$

where V is the amount of water needed in liters per day, given at level S of the micro-lysimeter. Irrigation of these plants was done with four different irrigation levels, and irrigation with the mentioned coefficients will be done in three repetitions. After a cultivation period, the amount of water needed will be determined, and finally, the crop coefficients will be determined. The soil used after the test has 32% clay, 35% sand, and 33% silt, which is in the medium texture group. The agricultural capacity of the soil is about 34, and the amount of available water is about 190 millimeters per meter. Soil water content and moisture stress of soil samples are measured and shown in Figure 5.

Figure 3. Different plant levels, irrigation, and repetitions



Source: Authors

Cultivation was done in 24 volumetric micro-lysimeters. The micro-lysimeter's height is 22 cm, its upper dimensions are 29.5x84, and its lower dimensions are 24x78 cm2. The weight of the empty micro-lysimeter is 1.970 kg, and with soil, it is 42.200 kg.

Figure 4. Daily min, max, and mean Temperature

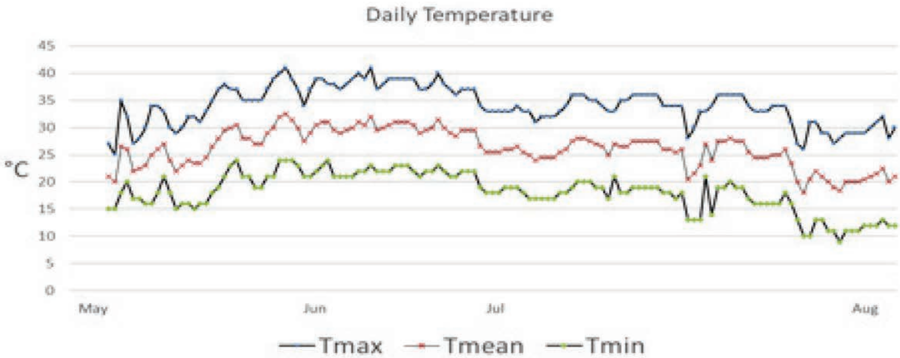


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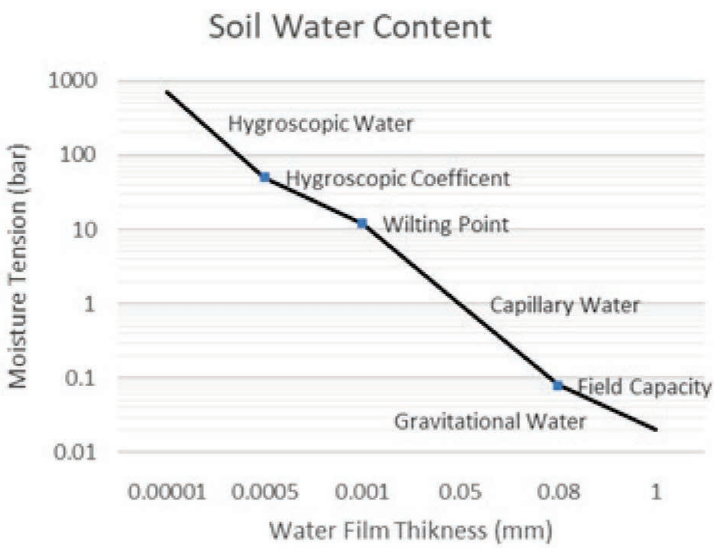
Figure 5. Soil Water Content and Moisture Tension



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3. RESULTS AND DISCUSSION

To investigate the effects of different water levels on the growth of experimental species, a factorial experiment was conducted in the form of randomized complete blocks, and the results were evaluated by simple analysis. Comparisons of averages were also performed based on Duncan's multi-range test. The results showed that the effects of sources of change, including species and irrigation water levels, and the mutual effects of these two studied traits (seedlings stem growth length in the species and the appearance of seedlings) were statistically significant at the 1% level. The results of trait variance analysis are included in Table 1. Based on this, the significance of the mean square of different irrigation levels for the height at the level of 5% indicated the difference in plant height in the different amounts of irrigation studied. In addition, the comparison of the mean height attribute based on Duncan's test is included in Table 2.

Table 1. Analysis of variance (mean square) of the evaluated attributes

Characteristics	**Height**	**Number of leaves**	**Number of folds**	**Number of stems**	**Number of flower buds**	**Stem diameter**
watering	127.91*	22405.1**	71.6**	72.14**	16.05**	248.84**
plant	4531.5**	41027.6**	537.8**	536.07**	46.57**	504.71**
interaction	37.7 ns	6067.6**	20.83**	20.93**	16.057**	17.09 ns
error	43.3	199.3 ns	0.421 ns	0.379 ns	0.449 ns	13.28
%CV	39.9	83.08	32.5	32.4	68.01	15.97
ns, *, ** They indicate no significant difference and significant difference at 5% and 1% levels, respectively						

Source: Authors

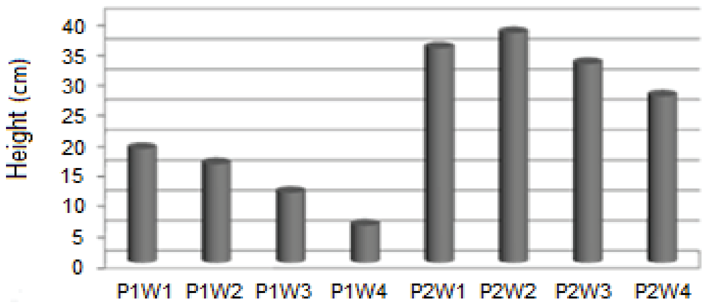
The significance of the mean square effect of the plant in terms of plant height showed the difference between planting different plants on the height trait (Table 1). In this regard, the maximum height was related to the Treven plant at 33.41 cm and the lowest value was related to the rose plant at 13.2 cm (Table 3). The evaluation of the average comparison of the mutual effect of different levels of irrigation and plant in terms of height was not significant (Table 4). The maximum height of 37.91 cm is related to treating the Treven plant with 80%-level irrigation (Figure 6).

Table 2. Comparison of the averages of studied traits at different levels of irrigation

Irrigation levels	**Height (cm)**	**Number of leaves**	**Number of stems**	**Number of flowers and buds**	**Stem Diameter (mm)**
100	18.07 a	111.1 a	8.99 a	2.47 a	18.56 a
80	18.07 a	74.44 b	7.11 b	1.33 b	5.95 b
60	14.8 ab	32.05 c	3.94 c	0.13 c	5.11 b
50	11.22 b	4.13 c	4.13 c	0 c	3.27 c
In each column, treatment levels with a common letter are grouped by Duncan's test at the 5% level in the same statistical group.					

Source: Authors

Figure 6. The mutual effect of different plant and irrigation levels on height



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The significance of the mean square of the effect of different irrigation levels on the number of leaves at the 1% level indicates that the use of different irrigation levels significantly differed in the number of leaves (Table 1). Therefore, according to the mean comparison (Tables 1 and 2), the highest and lowest number of leaves per plant was 111.1 and 15.13 for irrigation levels 100 and 50% (Table 2). The result of analyzing the variance of the number of leaves attribute is included in Table 1. Based on this, the significance of the mean square of different cultivars for the number of leaves at the 1% level indicates the difference in the number of leaves in the considered plants. The results (Table 3) confirm that Rose, with an average of 82.26, has the lowest number of leaves per plant, and Treven, with an average of 92.28, has the highest number of leaves per plant, and their difference is significant at the 5% level.

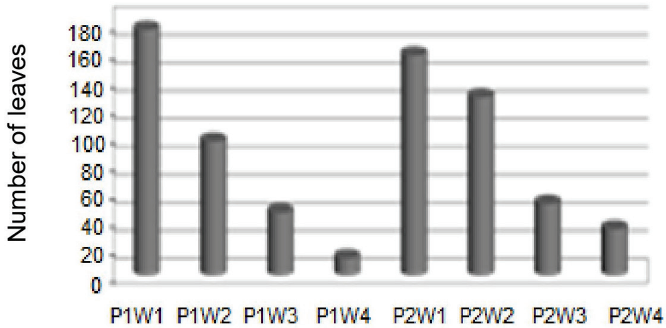
Table 3. The effect of the plant species on the evaluated properties

Plant	Height (cm)	Number of leaves	Number of stems	Number of flowers and buds	Stem diameter (mm)
Rose	13.2 b	82.26 a	6.58 b	2.95 a	8.53 b
Treven	33.41 a	92.28 a	11.55 a	0 b	16.22 a
In each column, treatment levels with a common letter are grouped by Duncan's test at the 5% level in the same statistical group.					

Source: Authors

Considering that the interaction effect of different levels of irrigation and plant on the number of leaves was significant at the 1% level (Table 1), this shows that the process of changes in the number of leaves in the plant was completely different at different levels of irrigation and the studied plant. So, the number of leaves increased when irrigation increased (Table 4). In this regard, the highest and lowest number of leaves are 175.83 and 12.41, respectively, for the rose plant with an irrigation level of 100% and the rose plant with an irrigation level of 50% (Figure 7).

Figure 7. The mutual effect of different plant and irrigation levels on the number of leaves



Source: Authors

Table 4. The effect of the plant species on the evaluated properties

Treatment	Height (cm)	Number of leaves	Number of stems	Number of flowers and buds	Stem diameter (mm)
P1W1	18.83cd	175.83a	9.91c	7.14a	10.45b
P1W2	16.28d	95.83d	9.08d	3.99b	9.61bc
P1W3	11.58e	44.95ef	3.24f	0.14c	8.49bc
P1W4	6.16ef	12.41g	4.08e	0c	5.24d
P2W1	35.41ab	157.49b	17.08a	0c	45.24a
P2W2	37.91a	127.49c	12.24b	0c	8.24bc
P2W3	32.83ab	51.16e	8.58d	0c	6.83cd
P2W4	27.49bc	32.99f	8.33d	0c	4.57d

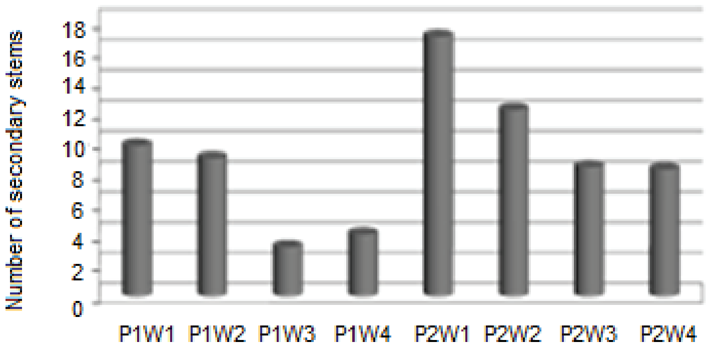
In each column, treatment levels with a common letter are grouped by Duncan's test at the 5% level in the same statistical group.
In the table, P1 represents the Rose plant, P2 represents the Treven plant, and W represents the irrigation level.

Source: Authors

The significance of the mean square of the effect of different irrigation levels on the number of stems at the 1% level indicates that the use of different irrigation levels significantly differed in the number of stems (Table 1). Therefore, according to the average comparison made by using Duncan's method and according to Tables 1 and 2, the highest and lowest number of stems per plant are 8.99 and 3.94 stems, respectively, corresponding to the irrigation level of 100%, and the irrigation level of 50% (Table 2). The significance of the mean square of different cultivars in Table 1 for the number of stems at the 1% level indicates the difference in the number of stems in the considered plants. The results (Table 3) confirm that Rose, with an average of 6.58, has the lowest number of stems per plant, and Treven, with an average of 11.55, has the highest number of stems per plant, and their difference is significant at the 1% level.

Considering that the interaction effect of different levels of irrigation and plant on the number of stems was significant at the 1% level (Table 1), this indicates that the process of changes in the number of stems in the plant was completely different at different levels of irrigation and the studied plant. So, with the increase in irrigation, the number of stems increased (Table 4). In this regard, the highest and lowest number of stems are 17.08 and 3.24, respectively, for the Treven plant with an irrigation level of 100% and the rose plant with an irrigation level of 60% (Figure 8).

Figure 8. The mutual effect of different plant and irrigation levels on the number of stems



Source: Authors

The significance of the mean square of the effect of different irrigation levels on stem diameter at a 1% level indicates that the use of different irrigation levels significantly differed in stem diameter (Table 1). Therefore, according to the average comparison made by Duncan's method and in Tables 1 and 2, the maximum stem diameter obtained was 18.56 mm, corresponding to 100% irrigation level, and the minimum stem diameter was 3.27 mm, corresponding to 50% irrigation. The analysis of variance (Table 1) and the significance of the mean square of different cultivars for stem diameter at the 1% level indicates the difference in stem diameter in considered plants. The results (Table 3) confirm that Rose, with an average of 8.53, has the lowest stem diameter per plant, and Treven, with an average of 16.22, has the highest stem diameter per plant. Their difference is significant at a 1% level. The evaluation of the average comparison of the interaction between irrigation levels and plants was insignificant in terms of stem diameter because the changes of this trait in each of the Rose and Treven plants were similar at different irrigation levels (Table 4). In this regard, the maximum and minimum stem diameters are 45.24 and 4.57 mm, respectively, for the Treven plant with an irrigation level of 100% and the Treven plant with an irrigation level of 50% (Figure 9). By dividing the actual evaporation and transpiration by the calculated evaporation and transpiration, the crop coefficient is obtained, which is drawn for different irrigation levels in the crop Evaporation and Transpiration diagram during the growth period (Figure 10).

Figure 9. Interaction effect of different plant and irrigation levels on stem diameter

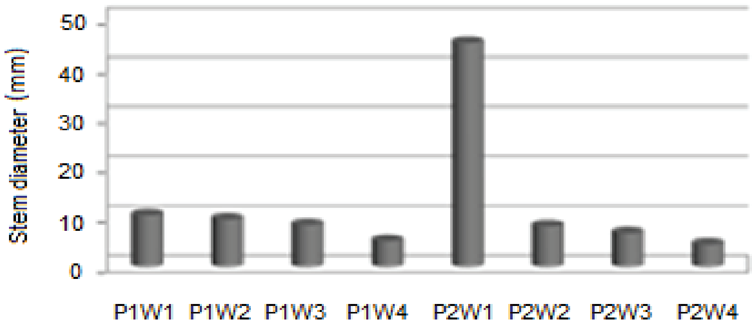


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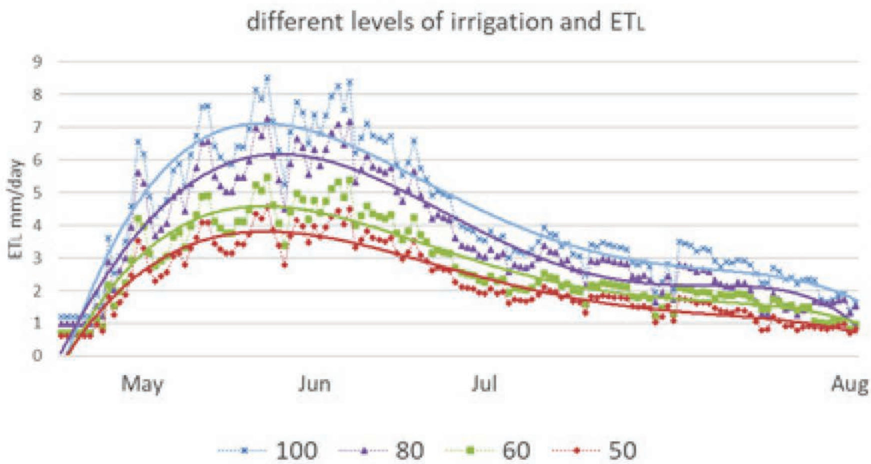
Figure 10. The results of different levels of irrigation crop Evaporation, and Transpiration



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4. CONCLUSIONS

The results show the significance of the mean square of the effect of different irrigation levels of potential evapotranspiration for the studied characteristics, indicating the significant impact of different irrigation levels for the mentioned characteristics. The irrigation level of 80% has an optimal effect on plant height and the number of buds and stem diameter compared to other levels (50% and 60%) of irrigation. In the years of water scarcity, for the stability of the plant, a minimum irrigation level of 60% is suggested for the Rose plant and a minimum irrigation level of 50% for the Treven plant.

Given the growing threat of climate change, adapting irrigation practices is crucial to ensure sustainable plant growth. We recommend further research into adaptive irrigation strategies, including advanced irrigation technologies and practices, to mitigate the adverse effects of climate change. Specific areas of focus should include implementing more efficient irrigation systems, such as drip irrigation, to reduce water use while maintaining plant health, developing and adopting rainwater harvesting systems to capture and store rainfall for use during dry periods, investigating the use of treated wastewater for irrigation, especially in areas facing water shortages, and identifying plants that are more resistant to such water sources, utilizing smart and online methods to diagnose and predict the water requirements of plants and to analyze and plan irrigation schedules.

ACKNOWLEDGMENT

The authors would like to express gratitude to Ms. Marina Laszlo for proofreading, editing, and improving the language and grammar.

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Izvorni znanstveni rad
https://doi.org/10.31784/zvr.13.1.14
Datum primitka rada: 10. 3. 2024.
Datum prihvaćanja rada: 23. 10. 2024.

PROCJENA UČINKA DEFICITNOG NAVODNJAVANJA NA BILJKE U URBANOM KRAJOLIKU U MASHHADU (RUŽA I TREVEN)

Jafar Hashempour
Dr. sc., docent, Sveučilište Ferdowsi u Mashadu, Zavod za vodne znanosti, Iran;
e-mail: jafar.hashempour@mail.um.ac.ir

Sara Dadar
Doktorandica, Sveučilište Ferdowsi u Mashadu, Zavod za vodne znanosti, Iran;
e-mail: sara.dadar@mail.um.ac.ir

Bojan Đurin
Dr. sc. izvanredni profesor, Sveučilište Sjever, Odjel za graditeljstvo, 42 000 Varaždin, Hrvatska;
e-mail: bdjurin@unin.hr

Marko Šrajbek
Dr. sc., docent, Sveučilište Sjever, Odjel za graditeljstvo, 42 000 Varaždin, Hrvatska;
e-mail: msrajbek@unin.hr

Domagoj Nakić
Dr. sc., docent, Sveučilište u Zagrebu, Građevinski fakultet, Zavod za hidrotehniku, 10 000 Zagreb, Hrvatska;
Sveučilište Sjever, Odjel za graditeljstvo, 42 000 Varaždin, Hrvatska;
e-mail: domagoj.nakic@grad.unizg.hr; dnakic@unin.hr

SAŽETAK

Istraživanje u ovom radu provedeno je u Mashhadu kako bi se analizirao učinak nedovoljnog navodnjavanja na krajobrazne biljke i odredile točne vrijednosti evapotranspiracije. Istraživanje je provedeno statističkom faktorijalnom analizom u potpuno randomiziranim blokovima s tri ponavljanja. Ruža i treven navodnjavani su u različitim količinama koje odgovaraju četirima razinama potencijalne evapotranspiracije: 50, 60, 80 i 100 % te su procijenjeni parametri visine biljke, promjera stabljike te broja listova i cvjetova. Rezultat je pokazao da različite razine navodnjavanja imaju značajan učinak na parametre biljke, a najbolji rast je postignut pri stopi navodnjavanja od 80 % potencijalne evapotranspiracije.

Ključne riječi: *potreba za vodom, krajolik, ruža, treven, biljni koeficijent, deficit navodnjavanja*