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The effect of microclimate and irrigation intervals on performance of urban landscape plants based on soil moisture measurement

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Abstract

In today's world, the growth of urban and suburban population has increasingly shifted the balance between the water demand and the available water resources. Moreover, the synchronization of maximum consumption of water in urban landscapes with the drinking water sector has caused the landscape to be a serious competitor for urban drinking water sources. This study investigates the effects of environmental variations at two locations (lake complex and city center park in Golbahar, Khorasan Razavi province, Iran), and irrigation intervals at three levels (daily, 2-day and 3-day) on some performance characteristics of urban landscape plants (height, root length, leaf relative water content, proline in lawn and mixed lawn, electrolyte leakage and stomatal conductance in lawn, mixed lawn and mixed tree) based on soil moisture measurements. Sensors were installed after calibration at depths of 0-10 cm for lawn and at depths of 0-10, 10-30 and 30-50 cm for mixed lawn and trees. The highest moisture depletion for lawn was observed in both locations due to the level of evapotranspiration in August, July, and June, respectively. In the city center park, the soil moisture percentage and soil adsorption rate at the time of irrigation as well as the rate of desorption was higher than the lake complex. In mixed lawn and tree pattern, the moisture content of the soil layers decreased with increase of depth, and the maximum desorption occurred in July and August. The effect of microclimate resulted higher lawn height value at the lake complex than the city center park, and there was no difference between the lawn and the mixed lawn. Also, with increase in irrigation interval, the height of lawn was significantly decreased. Moreover, the effect of location of irrigation and irrigation interval on root length was not significant. The relative water content percentage decreased 28 % in three-day irrigation compared to daily irrigation. For proline concentrations, only location and irrigation intervals were significant. The lower levels of electrolyte leakage indicated higher resistance of tree in similar irrigation conditions, which increased 12 percent with increase in irrigation intervals, from 1 to 3-day. The average stomatal conductance in the leaves indicated that it was less for the lawn than the tree in the same irrigation interval due to the greater resistance of the tree to drought against lawn. Upon the results, soil moisture sensors can be used as a tool in irrigation decision making which could contribute to water saving in amenity urban landscapes.

Key words: Soil moisture sensor, evapotranspiration, microclimate, irrigation intervals

Introduction

In today's world, the growth of urban and suburban population has increasingly disarranged the balance between the water demand and the available water resources. This was especially evident in arid and semi-arid areas of world, so in the near future, conservation and consumption reform plans, would be a special part of the water management programs for rapidly growing population. The rise of living standards in urban areas, such as sustainable transportation, efficient landscapes and various urban services has contributed to this disarrangement. On the other hand, the limited availability of water resources has led to a competition for water consumption in different parts of the world, which in some cases has caused conflicts between different parts. Due to the simultaneous over consumption of water in urban landscape and for drinking, landscape is considered as a major competitor for urban drinking water sources.

Regarding the planting of various varieties in green urban environment, water consumption in this combined level was a function of different variables such as number, level and type of plants in a location, climatic conditions and soil characteristics. In addition, there may be synergetic effects of multiple plant species on the total water consumption of landscape. On the other hand, urban areas are a combination of discrete and diverse spaces, and the existence of urban structures may change the microclimate by changing wind and airflow patterns, reflection of light, heat radiation and effects of shading, and thus affect the water demand of plants.

Cabrera *et al.* (2013) argue that population growth in urban areas of Texas will increase 82 % over the next 50 years; consequently, the urban water demand will increase about 71.4 % during the same period. Thus, they suggest use of innovative strategies, which could include selecting low need plants, smart irrigation controllers equipped with rain and moisture sensors and alternative water sources for irrigation.

Dukes (2012) compared several smart irrigation controllers that consist of soil moisture sensors, rainfall sensors and evapotranspiration-based controllers and he remarked more than 40 % divergence exist between the apparent potential saving and they realized saving in pilot projects are related to the lack of targeting of high irrigation users, education for interactors and end users and timely follow-up for access water saving. In addition, much of the scientific research on smart controllers has been conducted in humid regions where higher potential saving are likely due to irrigation needed only to supplement rainfall.

Water consumption reduces between 7 % and 30 % using rain sensors, between 0 and 74 % using transpiration sensors, between 25 % and 62 % using evapotranspiration sensors by a two-day irrigation program in a week (McCready *et al.*, 2009). The advantages of using rain sensors are reduction of water consumption, water costs, and the use of irrigation systems, the risk of diseases and the potential of contamination of surface and subsurface of soils (Dukes and Haman, 2010).

Williams *et al.* (2014) surveyed the literature on water saving associated with the implementation of three types of advanced irrigation controllers: rain sensors, weather-based irrigation controllers and soil moisture sensors. Their meta-analysis demonstrate that advanced irrigation controllers on an average can capture substantial water saving 38 % for soil moisture sensors, 21 % for rain sensors and 15 % for weather-based irrigation controllers. They suggested wider adoption of advanced irrigation control technologies would result in average water saving that could lessen the strain on aging water treatment infrastructure and exhausted fresh water resources.

Several soil water content sensor technologies along with an assessment of the performance of selected soil water content sensors have been done (Chavez and Evett, 2012). Their evaluation was focused on calibration, installation and accuracy of sensors and recommended that some of the studied soil water sensors have the potential to be used in irrigation water management schemes.

During irrigation studies conducted by Dukes *et al.* (2007) in residential areas of Florida, they found that the installation of monthly irrigation timers based on the evapotranspiration rate, reduced 30 % of irrigation during a 30-month period. During the two-year experiment, which was conducted in humid climate, irrigation savings from soil moisture controllers with one, two, and seven days of irrigation intervals varied from 27 % to 92 % comparing to time based irrigation without moisture sensor.

Baum-Haley (2014) revealed that the conservation potential from soil moisture sensor systems not only positively impacts water savings, but also efficient watering behavior. Research has shown that the potential for water savings from soil moisture sensor systems used for turf and landscape irrigation is at par, if not greater than, that accepted for weather-based irrigation controllers. However, the magnitude of savings may be greater in humid regions where most of the research has taken place.

Samiyani *et al.* (2012) examined the effect of drought stress on some biochemical indexes in four species of cover plants (*i.e. Lolium perenne* lawn, *Potentilla*, *Trifolium repens* and *Frankinia* sp) in landscape in four irrigation level of 25, 50, 75 and 100 % of water requirements of the examined lawn. The results showed that Frankinia species had the highest proline content and the lowest chlorophyll content, 75 % water treatment stress had the highest amount of proline, and control treatment had the highest chlorophyll content. For total soluble sugars, *Lolium perenne* and *Trifoloum repens* had the highest and lowest amounts, respectively. Moreover, *Trifoloum repens* had the highest antioxidant activity. Although several studies have been done by using different kinds of sensors in landscape water management, but simultaneous surveying the relations between soil moisture, types of single and mixed landscape plants with different microclimate conditions and evaluation of some performance characteristics of plant have not been done. The objective of this study was to use soil moisture sensors for evaluating the amount of soil moisture before and after different irrigation interval on single and mixed landscape plants with different microclimate situations. Indeed, we considered existence of coincidence between soil moisture sensing behavior and some performance characteristics of urban landscape plants.

Materials and methods

Test location, plant pattern and experimental design: This experiment examined the effect of environmental conditions and irrigation interval on some of the performance characteristics of the urban landscape plants including lawn, mixed lawn and trees. The lawn was a sport lawn with a combination of Lolium, Fescue and Poa species and the tree was Acacia. This research was conducted at the city of Golbahar. In order to investigate the effect of environmental conditions, we chose two locations, the tourist and recreational complex of the lake, which has vast areas of landscape and lake water, and the city center park which has the large surfaces of stone pavements and is surrounded with streets. We conducted the experiment between April 20th to September 20th, 2016 in the form of a completely randomized experiment with three irrigation intervals of daily, 2-day, and 3-day with 3 replications. The sprinkler irrigation system was used in places, rotary sprinkler in the lake complex and spray head sprinklers in the city center park.

Soil test: Some physical and chemical properties of the soil were tested for each location. Considering the depth of the installation of moisture sensors (*i.e.*, up to 50 cm depth of soil), sampling was done. For sampling, five samples (*i.e.*, a total of 10 samples) were selected separately from the aforementioned depth, and then they were spread and dried. Each five samples were mixed completely and a random sample of about three kg was selected and tested. In the lake complex, soil texture was loam based on soil texture triangle, pH value was 7.6, EC value was 0.9 dsm^{-1}, lime value was 24 %, organic carbon was 0.79 %, soil saturation was 46.49 %, the moisture value was 13.24 % in the field capacity and 8.1 % at the wilting point. In the city center park, soil was loam, pH value was 7.8, lime value was 10.8 % and organic carbon was 0.41 %, and the soil saturation was 30.67 % and the moisture value in the field capacity was 10.45 and was 6.8 % at the wilting point. In addition, for the lake complex, clay, silt and sand were 21, 42 and 37 % and for the city center park, 18, 30 and 52 %, respectively. Therefore, the soil of the lake complex stored more water than that of the park and the main reason was that this location had less sand; in other words, its soil texture was heavier.

Calibration of sensors: For calibration, it was required to have a pot with a capacity of about three kg for keeping soil, a sensor, a digital balance, a thread to fix the sensor in the pot and sufficient water to saturate the pots.

Initially, we measured the sensor weight (M_{sensor}) and then we

Fig. 1. Calibration of sensors

Fig. 2. Sensors installation

measured the empty pot weight (with pores for circulation of water was at the bottom) (M_{pot}). At this stage, we measured the initial weight of the soil, for which the sensor was calibrated. To do so, we poured about 12 to 15 cm of the soil into the pot and compressed it uniformly by pressing lightly to the ground. Then we placed the sensor electrodes slowly and vertically in the center of the pot inside the soil so that it was 3 to 4 cm far from the bottom of the pot. Following this step, the remaining volume of the pot was filled with soil, so that the sensor was completely placed inside the soil. In order to prevent the sensor from moving inside the pot, we fixed it to the body of the pot using a thread. After the above steps, the pot, sensor, soil and the fixing were weighed ($M_{ini\text{-}soil}$). Furthermore, after subtracting the weight of the pot, the sensor and the thread, the initial soil weight (M_0) was obtained in grams.

In this stage, we put 100 to 200 grams of the initial soil in a bag to obtain the initial soil moisture. We calculated the initial soil moisture by weighting the metal container heater (m_1) in grams. Placing soil sample of the bag into a metal container and weighting it (m_2) in grams. Placing the metal container with its soil inside the heater at 125 °C for 24 hours in order to bring the moisture to zero and weighing it immediately after leaving the heater (m_3) in grams

Calculating the initial moisture content (RH_0) in percentage using the following formula:

$$RH_0 = \frac{m_2 - m_3}{m_2} \times 100 \qquad (1)$$

The equation (2) was used to calculate the soil dry weight (M_s) in grams:

$$M_s = M_3 - M_1 \qquad (2)$$

In the next step, we saturated the soil in a container larger than the pot by pouring about two to three liters of water. The pot was placed in the container to be completely saturated and water was raised to the surface of the soil and the surface was wet. This stage lasted between 16 and 22 hours based on the soil texture. After taking out the pots from the container, it took about 7 hours to deplete water through gravity from the pots. Saturation of the soil should not be done from the top of the pot, due to the change of place of sensor.

After this stage, the pots were weighed for a period of 12 days and at different times, and at the same time, humidity, environmental temperature and soil temperature were recorded and then calibrated and formulated using the Excel software (Fig. 1).

Measuring soil moisture: To measure and record the moisture of the soil, the *REC-SEN V.7* sensors were installed in three specific areas, which varied with the depth of plant root zone (Fig. 2). For the lawn pattern, the depth of sensor installation was 0-10 cm, for the mixed lawn and tree; we had three installations with depth of 0-10, 10-30 and 30-50 cm. We read the data from the sensors by connecting to a data logger type *REC-56* manufactured by the Parsian Hydronic Company at two intervals of half an hour after and before each irrigation.

The recorded data included soil moisture content, soil temperature and environmental temperature.

Gathering data of sensors and recording them by data logger, as well as gathering data from evaporation and meteorological devices was conducted daily over a period of five months. At the beginning of the study, soil moisture changes were measured and recorded based on the current irrigation conditions of landscapes, which was done as irrigation intervals for lawn and mixed lawn and trees. After that, application of irrigation intervals was done every day, every other day and in three days for plant patterns; soil moisture changes were again measured and their changes were examined. It was noteworthy that there was no change in different irrigation intervals during the period of irrigation. We tested and measured the performance characteristics of plant patterns at the end of the aforementioned period.

Examination and measurement of performance characteristics: We tested and measured some performance characteristics of different plants in order to determine the optimal irrigation interval and to evaluate the performance of the sensors.

Lawn performance characteristics

Height growth: Because of mowing operation every 15 days, height growth rate was measured from the end of one mowing operation until the beginning of the next mowing operation. Measurement of lawn growth height was done by a scaled ruler that zero of the ruler was placed at the soil level. For each measurement, the results were read three times. We considered the mean of each measurement.

Rooting depth: Maximum lawn rooting depth was measured in order to examine the depth of lawn rooting at the end of different irrigation intervals. Thus, for each time, two 30 x 30 cm square pieces of the lawn were separated and then a sample with 10 cm diameter was separated, then the length of the root was measured at three points after washing the roots. We calculated the mean for each time of the measurements. At this stage, the rhizomes and stolons were accurately separated.

Leaf relative water content: Relative leaf water content is a good indicator of water status in plants and provides a more comprehensive picture about balance between the leaf water supply and transpiration rates. In order to measure the relative leaf water content sampling was done, using scissors from the last developed leaf of the lawn in all experimental treatments, and the samples were immediately placed in the ice and in the laboratory, their wet weight was measured with a precision scale (the leaves should not be broken or fractured). Then all the samples were placed in distilled water in a refrigerator at 4° C for 24 hours. After 24 hours, the saturated weight of the leaves was measured and the leaves were placed in the oven for another 24 hours at 70° C and the dry weight of each was measured. By placing the numbers obtained by a precision scale with accuracy of one in ten-thousandth in equation (3), the amount of relative leaf water content was obtained.

$$RWC= \frac{P_W-D_W}{S_W-D_W} \times 100 \quad (3)$$

Where,

RWC: Relative water contact (%)
F_W: Weight of wet leaf after sampling (g)
D_W: Weight of dry leaf after ovening (g)
S_W: Weight of saturated leaf after distrilling (g)

Electrolyte leakage: Measurement of leaf electrolyte leakage is one of the best methods for determining the membrane stability index and specifying the amount of oxidative damage of phospholipids of plasma membrane caused by full oxidation of free radicals. The membrane in plant cells is responsible for transporting substances and the regulating cytoplasm. Therefore, when membrane permeability is lost due to severe drought stress, the cell loses its efficiency and intracellular salts leak into the extracellular space. For this purpose, relative permeability of membrane was measured at the beginning and end of the period. In this method, the leaves of the lawn were first divided into 1 to 2 cm pieces and were placed in the test tube. Then, 20 mL of deionized distilled water was added to each of the samples. For each sample, about 0.5 to 0.8 g of fresh leaf was used. After about 30 seconds, the electrical conductivity of each sample was measured using EC meter.

The samples were kept at 4 °C for 24 hours, and the electrical conductivity was measured again. Then the samples were placed in an autoclave for 15 minutes and after being cooled at room temperature, the electrical conductivity was measured for the third time. Then, the percentage of electrolyte leakage was calculated by equation:

$$\text{Relative Permeability}= \frac{EC_1-EC_0}{EC_2-EC_0} \times 100 \quad (4)$$

Where,

EC_0: Electrical conductivity after 30 seconds (µmho.cm^{-1})
EC_1: Electrical conductivity after 24 hours (µmho.cm^{-1})
EC_2: Electrical conductivity after putting in autoclave (µmho.cm^{-1})

Proline content: Proline is a free amino acid which accumulates naturally in plant cells as a soluble substance in response to stress. Proline's essential role is protecting cells against the negative effects of salt accumulation, osmotic exchange, stability of cell structure, such as membranes and proteins. The amount of proline increases with increase in drought stress. In fact, proline accumulation is a general reaction under drought stress. For proline estimation, aerial parts of the plant were removed and dried in the oven at 70 °C for 48 hours, and then the dried samples were grinded and prepared and proline was estimated as per Bates *et al.* (1973).

Stomatal conductance: In general, crop growth was reduced under drought stress due to the restriction of photosynthesis. The limiting factors of photosynthesis are divided into two categories, stomatal factors that reduce the emission to intercellular space due to reduced stomatal conductance of CO_2, and nonstomatal factors that limit photosynthesis through direct impact of water deficit on biochemical processes of carbon processing. Examining the changes of stomatal and nonstomatal factors limiting photosynthesis under drought stress helps to identify the effective factors of resistance to this stress.

To measure the stomatal conductance, SC-1 promoter was used. This device was made up of a sensor that was connected to a display. The following steps were considered for starting the measurement of stomatal conductance. Before using the sensor, it was adjusted to the ambient temperature. The duration of this adjustment was as per temperature difference between the position of the sensor and the surrounding area, and took up to 10 minutes if the difference was significant.

Performance characteristics of the tree: For this, the characteristics which were evaluated include electrolyte leakage and stomatal conductance, which are described in detail in the sections above.

Results

The results of reading of sensors were picked by data logger and the obtained data were analyzed and converted to moisture content based on calibration equations of the sensors for plant patterns and different depths in the period of April 20th to September 20th.

The results of the moisture change showed that with increasing irrigation interval, the maximum and minimum of moisture had a descending trend and maximum of moisture depletion had an ascending trend at both sites (Table 1).

In the mentioned time, the maximum moisture content was more than field capacity for three irrigation intervals in the lake complex, and the minimum in daily and 2-day irrigation interval was between field capacity and wilting point and was close to wilting point in 3-day interval. In the city center park, the maximum and minimum moisture content was higher than the field capacity except for the 3-day interval. In similar irrigation interval, although the maximum and minimum of moisture in lake complex were less than these amounts in city center park, but the maximum depletion for two and three day interval was more in city center park because of the lighter soil texture in this

Table 1. Moisture changes for the lawn pattern

	Lake complex			City center park		
	Max. moisture content (%)	Min. moisture content (%)	Max. moisture depletion (%)	Max. moisture content (%)	Min. moisture content (%)	Max. moisture depletion (%)
Daily	15.1-18.6	9.2-10.6	4.6	17.4-26.5	13.4-17.9	4.5
2-day	14.2-17.3	8.8-10.7	5.2	15.3-23.5	10.1-15.1	6.5
3-day	13.6-17.4	8.4-11.4	5.7	15.1-22.5	9.2-14.9	6.6

place. The maximum depletion was approximately equal for daily interval in both sites.

In the similar period, the maximum moisture content was more than the field capacity for three-irrigation interval in the lake complex, and the minimum in daily and two-day irrigation interval was between field capacity and wilting point which was close to wilting point in three-day interval. In the city center park, the maximum and minimum moisture content was higher than the field capacity except for the three-day interval. Moisture content values measured by two sensors indicated that in all irrigation intervals, soil moisture content was higher despite of having a lighter soil, but soil moisture depletion of this site was faster than similar periods. This can be due to the type of sprinklers *i.e.*, spray-type, which spray more water per unit of time than rotary sprinklers in the lake complex (Figs. 3 & 4).

For the mixed lawn and tree pattern, due to the installation of three sensors at different depths, the results illustrated that in the lake complex, the maximum and minimum moisture contents had a descending trend with increasing depth for all irrigation intervals. In addition, the maximum moisture depletion in 0-10 and 10-30 cm depth had maximum values between all irrigation intervals which demonstrate that most root zone was in depth of 0-30 cm of soil (Table 2).

In the city center park, the maximum and minimum moisture contents had a descending trend with increasing depth for all irrigation intervals too. Moreover, in daily irrigation, although the maximum moisture depletion had no specific trend, but in 2 and 3 day irrigation interval, the maximum moisture depletion in 0-10 and 10-30 cm depth had maximum values between all irrigation intervals which demonstrate that most root zone was in depth of 0-30 cm of soil.

In addition, comparison of maximum moisture depletion in different sites illustrates that this value in city center park was more in lake complex in similar depths, which represents the shading role of tree (different microclimate situation) in preventing evapotranspiration and lighter soil texture, despite the competition for water absorption in the mixed pattern.

The process of change in moisture was identical in 10 and 30 cm sensors, but it was the opposite of the two other sensors in sensor 50, which means moisture was the minimum in the other two sensors. In addition, the third sensor recorded the highest moisture on the same day. Moreover, with increase in depth, moisture depletion as well as the level of moisture decreased. The decrease in the moisture was due to the type of irrigation system (*i.e.*, sprinkler) which caused the moisture pattern to be higher in surface depths and due to surface depletion, this rate reduced in other depths (Figs. 5 & 6).

Comparing the installed sensors in the two locations in similar irrigation periods shows that although the maximum and minimum moisture content in the city center park was higher, the amount of moisture depletion was higher for the city center park than that of the lake in the same depth.

Analysis of performance characteristics: We examined the performance characteristics of height, root length, relative water content of leaf and proline concentration for the two lawn and mixed lawn patterns. Moreover, we examined the pattern of lawn, mixed lawn and mixed- tree, two features of electrolyte leakage and stomatal conductance. We analysis the results with Minitab16 software based on a completely randomized design with factorial experiment (Table 3)

According to the results of analysis of variance (Table 3), the impact of variation sources indicates that the effect of irrigation interval at 1 % level and the effect of plant pattern at 5 % level were significant on the lawn height. In contrast, the mutual effect of variation sources which are location and plant pattern were insignificant on the lawn height. In other words, planting location

Table 2. Moisture changes for the mixed lawn and tree pattern

Day	Sensor depth (cm)	Lake complex			City center park		
		Max. moisture content (%)	Min. moisture content (%)	Max. moisture depletion (%)	Max. moisture content (%)	Min. moisture content (%)	Max. moisture depletion (%)
Daily	0-10	13.0-17.0	8.1-9.7	4.2	15.9-18.3	10.6-11.4	5.5
	10-30	11.5-15.4	7.4-9.1	4.1	14.8-17.5	9.6-10.3	4.0
	30-50	10.5-12.9	6.3-7.5	3.8	13.0-17.0	7.8-8.8	5.2
2-day	0-10	12.7-17.1	10.4-13.3	3.3	14.4-16.8	8.9-10.9	5.6
	10-30	12.0-15.9	7.8-10.7	4.6	13.4-15.8	8.1-10.0	5.2
	30-50	9.8-11.7	6.7-8.2	2.8	9.8-11.4	6.5-7.8	3.6
3-day	0-10	12.0-17.3	9.9-13.3	4.0	12.6-18.0	7.8-12.0	4.8
	10-30	11.5-16.7	8.3-12.0	4.3	11.2-16.9	7.0-11.5	4.2
	30-50	10.5-15.9	8.0-11.5	3.6	8.5-15.4	6.3-11.1	2.9

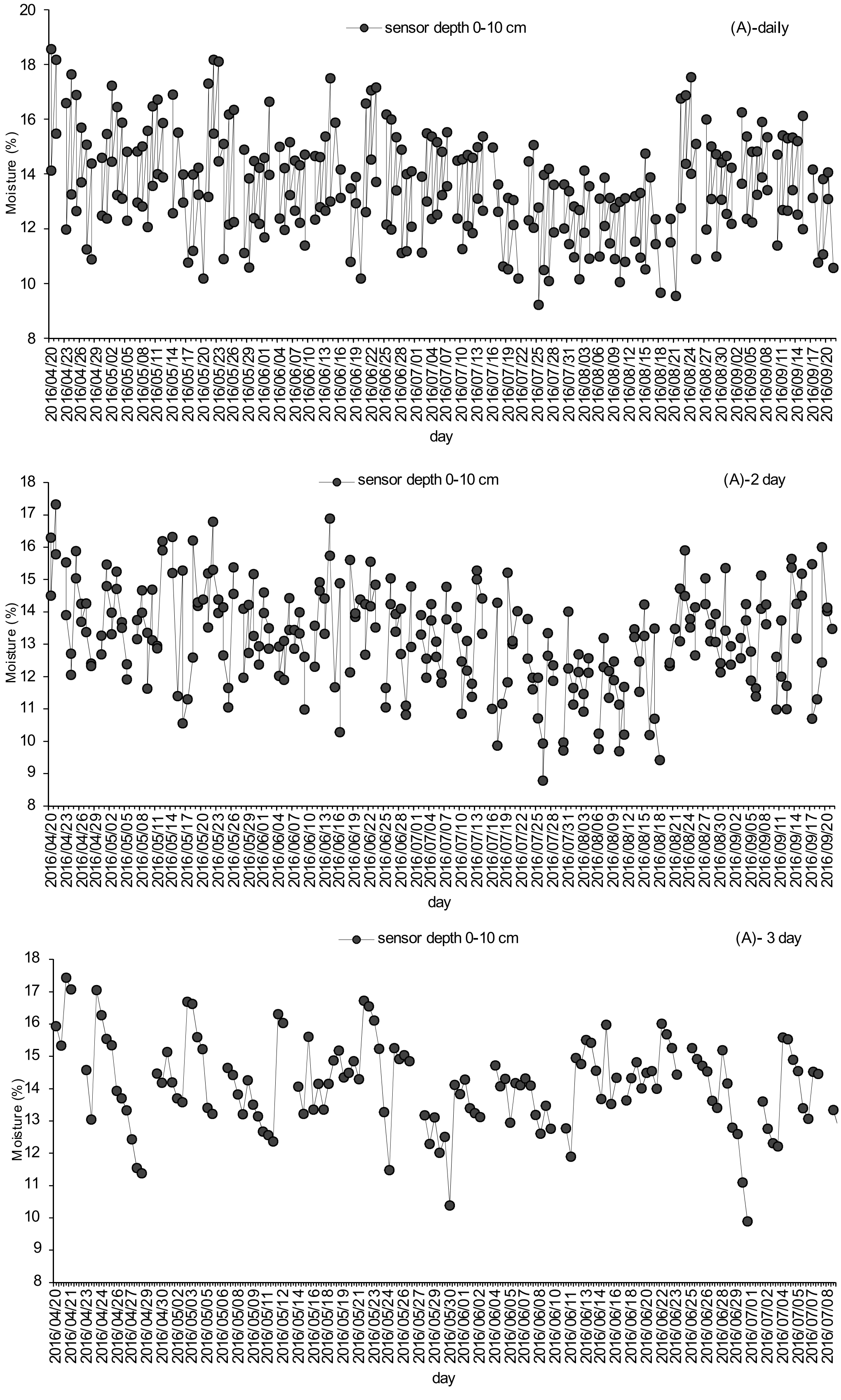

Fig. 3. Lawn moisture content variation in different irrigation intervals in the lake complex

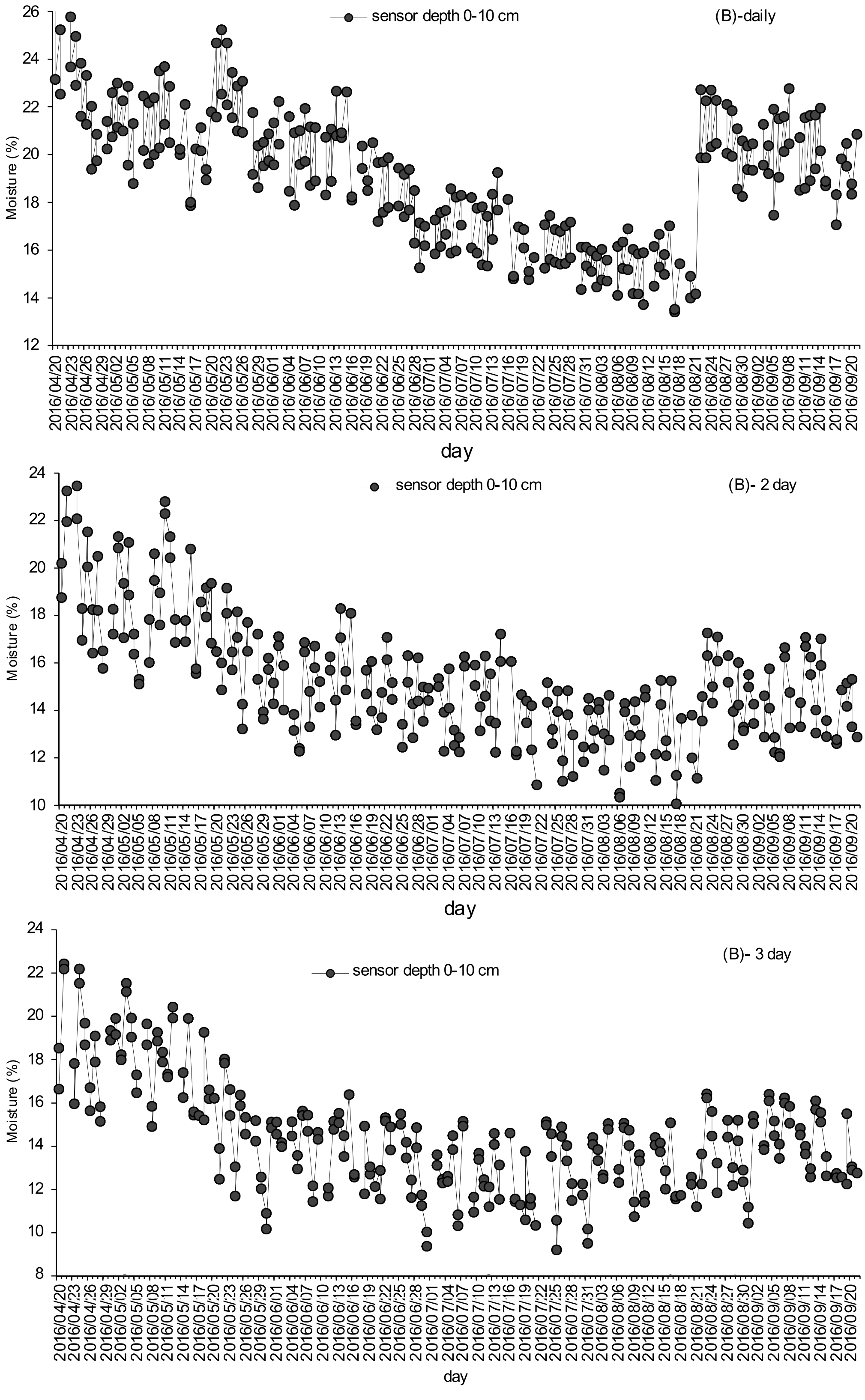

Fig. 4. Lawn moisture content variation in different irrigation intervals in the city center park

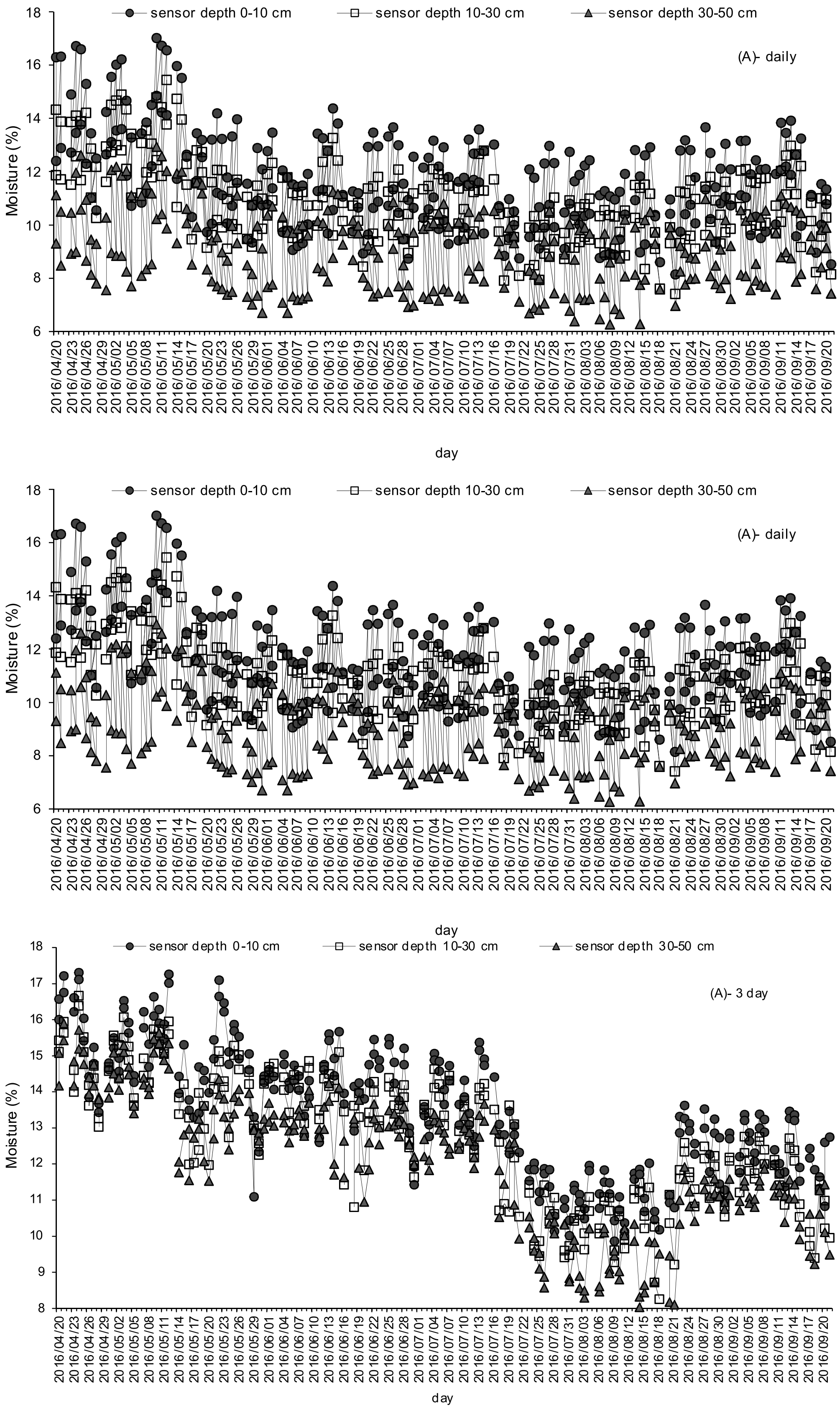

Fig. 5. Mixed lawn and tree moisture content variation in different irrigation intervals in the lake complex

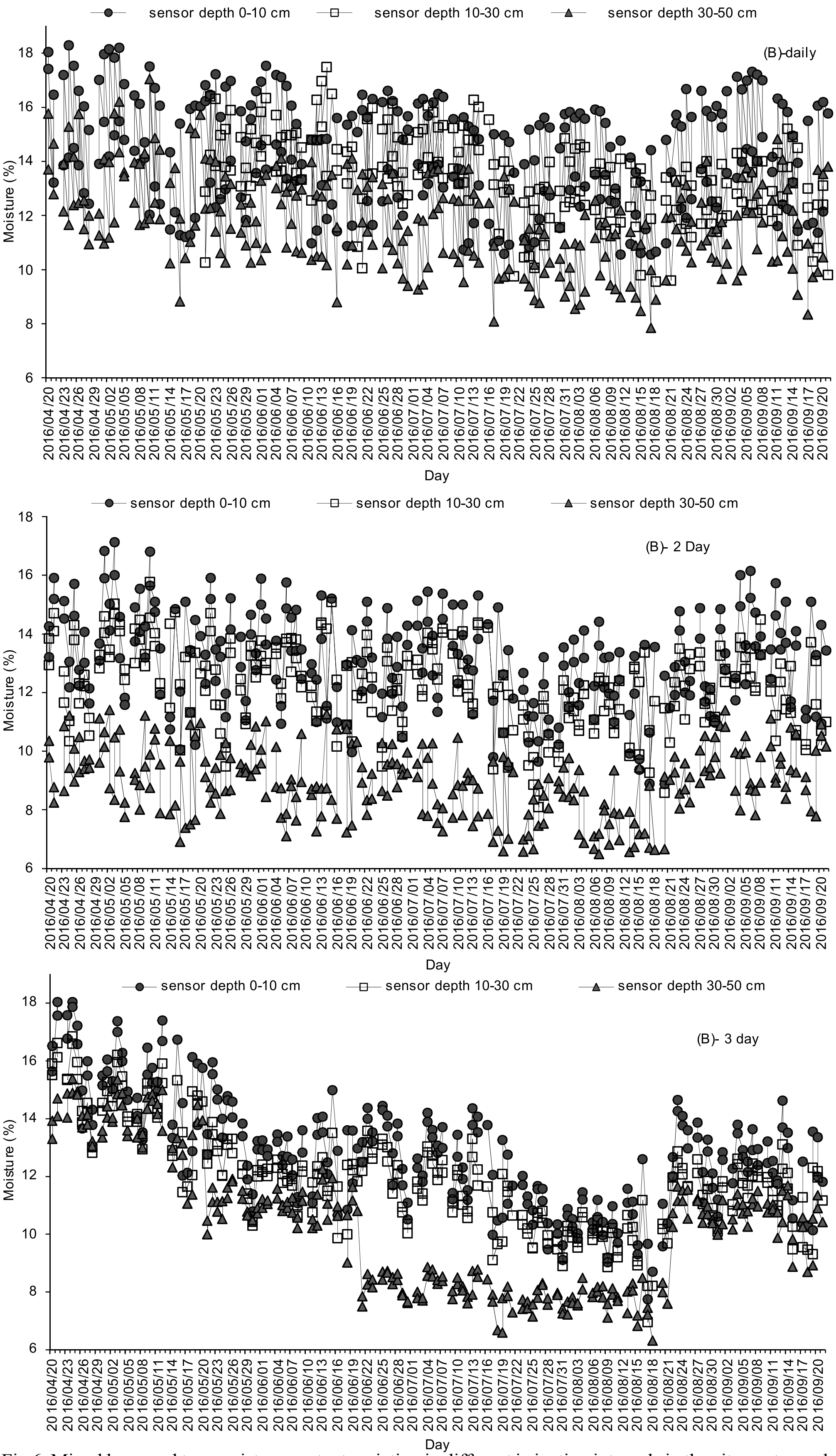

Fig 6. Mixed lawn and tree moisture content variation in different irrigation intervals in the city center park

Table 3. Mean squares of variance analysis for effects of place, type of landscape and irrigation interval

Sources of variations	df	Height	Root depth	Leaf RWC	Proline
Place	1	**0.72	ns 0.05	*59.60	**26.88
Type of landscape	1	*0.30	**3.55	*68.72	ns 0.53
Irrigation Interval	2	**4.51	ns 0.14	**2552.32	**7.16
Place x Type	1	0.23ns	ns 0.03	ns 13.54	**3.48
Place x Irrigation Interval	2	0.10ns	ns 0.07	ns 1.50	*1.40
Type x Irrigation Interval	2	0.09ns	ns 0.08	**228.61	ns 0.77
Place x Type x Irrigation Interval	2	0.01ns	ns 0.15	ns 0.25	*1.95
Error	24	0.09	0.14	15.88	0.40
Total	35				

ns: not significant *: significant at 5 % **: significant at 1 %

was statistically significant on lawn height for similar irrigation intervals and similar species, also lawn height difference for a location and similar pattern was significant at 1 % level for different irrigation intervals. In addition, height difference for a lawn, which was planted separately and a lawn, which was planted with tree was statistically significant for a location at 5 % level and similar irrigation intervals.

On the other hand, according to analysis of variance for root length factor, plant pattern was only significant at 1 % level and in other cases no significant difference was observed.

For performance characteristics of relative leaf water content, the impact of location and plant pattern was significant in 5 % level and the mutual effect of irrigation interval was significant in 1 % level in plant pattern, but it was insignificant in other cases. In other words, for similar irrigation intervals, change in planting location and change in plant pattern were significant on relative leaf water content in 5 % level. In addition, for a similar location and plant pattern, changes in relative leaf water content were significant on the effect of changes of irrigation in 1 % level.

However, the greatest amounts of variations in various sources are related to proline concentration. It means that, the effect of location, irrigation interval and mutual effect of location and pattern on these performance characteristics was significant at 1 %, and mutual effect of location in irrigation interval and location in pattern was significant at 5 %. However, the effect of plat pattern separately, and mutual effect of irrigation interval in pattern had no significant difference at any statistical level. In other words, the effect of location and irrigation interval changes caused the greatest change of proline concentration in the same species.

The results obtained indicate that the mean height of lawn in the lake complex was more than the city center park and has a significant difference (Table 4). In addition, in the mixed-lawn pattern, the mean lawn height was 2.71 cm but it was 2.52 cm in the lawn pattern, which did not have a significant difference. Moreover, the examination of the mean of lawn height, which was affected by change of irrigation interval, showed that the highest mean was 3.16 cm and belonged to daily irrigation, and the minimum was 1.95 cm and belonged to the 3-day irrigation interval and there was a significant difference between the irrigation intervals in all irrigations.

There was no significant difference between the two locations in terms of performance characteristics of root. However, the mean of root length in the lawn pattern was 5.30 cm and it was 4.67 cm in the mixed-lawn, which was statistically significant (Table 4).

There was no significant difference between root length in the irrigation intervals, but the larger the irrigation interval, the smaller was the length of the root and it varied from 5.09 in daily irrigation interval to 4.77 cm in a 3-day irrigation interval.

Analysis of the mean of relative leaf water content indicated that although there was no significant difference between the mentioned locations and lawn and mixed lawn patterns, this factor had a significant difference for daily, 2-day and 3-day irrigation intervals. The mean of leaf relative water content indicated that this amount was greater in the lake complex than the city center park. This is attributable to the effect of the microclimate. For the mixed lawn the microclimate effect was more than the lawn pattern, indicating the effect of tree shading on keeping part of the lawn leaf relative water content. In addition, in daily irrigation interval, the leaf relative water content reached 64.99 % and in the 2-day irrigation interval it reached to 55.79 % and in the 3-day interval it reached 36.42 %.

Although there was no significant difference in proline concentration between lawn and mixed lawn patterns, this difference was significant for the proposed locations and irrigation intervals. The mean of proline concentration was 1.23 and 2.96 mg in gram of wet weight for the lake complex and city center park respectively, which indicate a significant effect of

Table 4. Mean comparison on height, root depth, leaf relative water content and proline concentration for the lawn and mixed lawn

Treatments		Height (cm)	Root depth (cm)	Leaf RWC (%)	Proline (mg/g wet weight)
Place	Lake complex	2.76 a	4.95 a	53.69 a	1.23 a
	City center park	2.47 b	5.02 a	51.11 a	2.96 b
Type of landscape	lawn	2.52 a	5.30 a	51.02 a	1.97 a
	Mixed lawn	2.71 a	4.67 b	53.78 a	2.22 a
Irrigation interval	daily	3.16 a	5.09 a	64.99 a	1.26 a
	2-day	2.73 b	4.99 a	55.79 b	2.24 ab
	3-day	1.95 c	4.88 a	36.42 c	2.79 b

For each column and factor, there is no significant differences between the numbers that have at least one common letter at a probability level of 1 % based on Turkey test.

microclimate, which decreases drought stress in the lake complex compared to the city center park. Moreover, proline concentration in daily irrigation was the lowest and equal to 1.26 mg / g of wet weight and in the 3-day irrigation, it was the highest and equal to 2.79 mg in gram of wet weight. These values have significant difference between daily and 3-day irrigation intervals, but this difference was not significant between daily and2-day irrigation and 2-day or 3-day irrigation. Therefore, irrigation intervals of lawn can be increased from daily to 2-day.

The plant patterns are classified as lawn, mixed lawn and mixed tree for analyzing the performance characteristics of electrolyte leakage and stomatal conductance during irrigation periods of up to 3-day (Table 5).

Table 5. Mean squares of variance analysis for effects of place, type of landscape and irrigation interval on electrolyte leakage and stomatal conductance for lawn, mixed lawn and mixed tree

Sources of variation	df	Electrolyte leakage	Stomatal conductance
Place	1	^{ns} 28.22	** 280.62
Type of landscape	2	2091.45**	** 97.65
Irri. interval	2	629.78**	220.18**
Place x Type	2	^{ns} 2.75	* 30.10
Place x Irri. interval	2	^{ns} 15.60	^{ns} 17.67
Type x Irri. interval	4	** 216.98	** 35.63
Place x Type x Irri. interval	4	* 30.11	25.81*
error	36	8.66	8.75
total	53		

ns: not significant, *: significant at 5 %, **: significant at 1 %

Based on the results of analysis of variance (Table 5), the effect of variation sources on the above mentioned functions, indicated that the effects of plant pattern, irrigation interval and mutual effects of irrigation interval in plant pattern were significant at 1 % level; Mutual effect of location, plant pattern and irrigation interval at 5 % was significant in electrolyte leakage. However, the effect of location, mutual effect of location in plant pattern and location in irrigation interval was insignificant in electrolyte leakage. In other words, in a similar location, the type of plant pattern and irrigation interval affected the leakage. Interestingly, the greatest amount of variation of different sources was related to stomatal conductance. This implies that the effect of location, plant pattern, irrigation interval and mutual effect of irrigation interval in the pattern was significant on this performance characteristic at 1 % level, and the impact of mutual effect in the pattern and the mutual effect of location in pattern in the irrigation interval was significant at 5 % level. However, the mutual effect of location in irrigation intervals was not different at any of the statistical levels. In other words, the effect of location change and irrigation interval change caused the greatest change in stomatal conductance of the same species.

Investigating the performance characteristics mentioned above shows that in general, the greatest impact was due to changes in irrigation intervals and difference in plant pattern.

Comparing the mean of the effect of location, type of plant pattern and irrigation interval on electrolyte leakage and stomotal guidance of lawn, mixed lawn and mixed tree, shows that the mean of electrolyte leakage in the city center park was larger than the lake complex, but did not have a significant difference. In addition, there was no significant difference in electrolyte leakage in lawn and mixed lawn pattern, but for the mixed- tree pattern, the amount of electrolyte leakage reached from the highest amount in the lawn *i.e.*, 93.38 to 74.34 % in this pattern that shows a significant difference with two lawn patterns. Moreover, the mean of leakage affected by irrigation variation showed that the highest mean was 92.46 % and belonged to 3-day irrigation and the lowest was 80.65 % and belonged to daily irrigation interval and there was just significant difference in electrolyte leakage between a 3-day irrigation interval with other irrigations. In other words, there was no significant difference between daily and 2-day irrigation intervals.

Table 6. Mean comparison on electrolyte leakage and stomatal conductance affected by place, type of landscape and irrigation interval

Treatment		Electrolyte leakage (%)	Stomatal conductance ($mmol.m^{-2}.s^{-1}$)
Place	Lake complex	86.05 a	14.11 a
	City center park	87.50 a	18.67 b
Type of landscape	Lawn	93.38 a	15.93 a
	Mixed lawn	92.62 a	14.33 ab
	Mixed tree	74.34 b	18.92 b
Type of landscape	Daily	80.65 a	20.06 a
Irrigation interval	2-day	87.23 a	16.03 b
	3-day	92.46 b	13.09 b

For each column and factor, there is no significant differences between the numbers that have at least one common letter at a probability level of 1 % based on Turkey test.

The examination of means of stomatal conductance in leaves indicate that for the mentioned locations, this difference was significant, which was 14.11 $mmol.m^{-2}.s^{-1}$ for the lake complex, and 18.67 $mmol.m^{-2}.s^{-1}$ for the city center park. For lawn pattern and mixed lawn or mixed tree, the change in value of this index was insignificant, but it was significant between lawn and mixed-tree pattern. Due to the lower value for lawn compared to tree, it can be concluded that in a similar irrigation interval, the amount of resistance of the tree to drought was more than the lawn.

For irrigation intervals, the average of stomotal guidance value reached from 20.06 $mmol.m^{-2}.s^{-1}$ in daily irrigation to 13.09 $mmol.m^{-2}.s^{-1}$ in 3-day irrigation, which according to the analysis data, there was a significant difference between daily irrigation interval and other irrigation intervals.

Discussion

Regarding the selected plant patterns of lawn and the mixing of lawn and trees and irrigation intervals, as well as depth of installation of moisture sensors, the results show that for lawn pattern, the highest moisture depletion was in August, July and June for both locations and, consequently, evapotranspiration. Although, during irrigation, soil moisture percentage and loading rate of soil moisture capacity were greater in the city center park than the lake complex due to bigger particles in the soil texture of the park, the moisture depletion of this location also occurred at higher speeds in similar irrigation intervals, despite the similar soil texture in two locations based on the soil texture triangle. This suggests the extremely severe effects of granulation and soil texture on water holding capacity.

In the pattern of mixed lawn and tree, the results of the installation of three sensors at different depths showed that with increase in depth, the moisture content of these layers decreased, which was due to two reasons: first, using sprinkler irrigation system which resulted in no deep percolation and inappropriate distribution of soil wetting. Second, the development of lawn root and tree in the upper layers resulted in more moisture absorption from these layers, which was also evident in the moisture depletion recorded in different months, such that the maximum depletion occurred in two upper layers.

Furthermore, in the city center park, the maximum moisture content was more than that of the lake at similar depths and times, which was due to more precipitation rate at the irrigation system of the city center park, and faster depletion of soil due to the presence of bigger particles in the soil texture.

Comparing two patterns of lawn and mixed lawn and tree in the irrigation intervals and similar months indicated that moisture depletion of the lawn was more due to the existence of a shading tree on the lawn and its major effect in preventing the evapotranspiration of the lawn.

The results indicated that microclimate affected the lawn height and the mean of this value was more in lake complex than the city center park, but there was no difference between the lawn and the mixed-lawn in height. In addition, with increase in irrigation interval, the height of lawn decreased. On the other hand, not only the location, but also the irrigation intervals had no effect on the root length of lawn. The results for leaf relative water content showed that changes in location and pattern did not have any significant effect on the content, and only the effect of irrigation interval was significant, in the sense that the leaf relative water content decreased 28 % in a 3-day irrigation decreased compared to daily irrigation. For proline concentration, the difference was significant for these two locations and irrigation intervals and the lower concentration in the lake complex compared to the city center showed the effect of the microclimate of the area. On the other hand, the results show that the lawn could resist against the 2-day drought stress in both sites.

Based on the analysis of common performance characteristics between the lawn, the mixed-lawn and the mixed-tree and regarding electrolyte leakage, the value was less for the mixed lawn than that for lawn. This value was least in mixed tree that showed a greater tree resistance under the same conditions of irrigation. On the other hand, comparison of this value for irrigation intervals indicated that this value increased 12 % with increase in irrigation interval from 1 to 3 day. Examination of the means of stomatal conductance in leaves indicated that this value had significant difference for the two locations. On the other hand, this value showed that in same irrigation intervals, tree resistance to drought was more than lawn. In the same irrigation period, the tree's resistance to lawn was higher. Indeed, with increasing in irrigation interval and drought stress, this value was reduced.

Conclusion of these results indicates that, in urban landscapes, it was possible to reduce the water consumption by selecting appropriate species and mixing their plantation and creating specific climatic conditions. Considering that lawn was affected more than other species by the water and environmental stresses, it was possible to reduce water consumption by mixed plantation and providing suitable shading conditions. Moreover, the results of irrigation interval analysis indicated that, although the severe increase of irrigation interval can cause stress in the performance characteristics of landscapes, in many plant species and different months of the year, the change in irrigation interval did not change the indexes significantly. Also, use of moisture sensors and water flow controllers can be helpful in assessing the moisture content available to plants in soil layers where root zone has been formed, which results in effective irrigation planning and implementation of precision irrigation.

In order to complete and develop effective research on estimating the evapotranspiration of landscape plants, and consequently water management in urban landscapes and reaching sustainable urban environment, the following suggestions are proposed:

(i) Process of moisture change is examined for different mixtures of landscape plants and different soil texture by soil moisture sensors, considering the effect of soil texture and different species of plants. (ii) Regarding the importance of lawn cover in most of urban landscapes, and considering the role it plays in improving the urban environment, steps should be taken to mix this species with other species and the measurement of water consumption and reaching the optimum state. (iii) Since the quality and appearance of urban landscapes are relatively based on their location, different climatic conditions, availability of safe water resources and the expectation of urban managers, it was possible to categorize and classify urban landscapes based on these indicators, and avoided the same definition of indicators in a city for its landscape. Based on this explanation, it was suggested to evaluate the water consumption in these classifications and formulate them as a comprehensive plan for each city. (iv) Considering that the majority of urban landscapes belong to boulevards and fields, and with regards to microclimate conditions of these areas due to the existence of thermal islands such as streets asphalt; soil moisture measurement was performed based on using mulch for trees and hedges. Growth indexes were also considered in addition to measurement of water requirement, and the classification was performed. (v) Due to the fact that in the major parts of the country, the irrigation of lawn is carried out on a daily basis as a result of high daily evapotranspiration in warm season; a study could be conducted based on the control of longitudinal growth (mowing height), color and other apparent indicators, based on irrigation interval changes or daily irrigation. (vi) Due to the extensive utilization of sprinkler irrigation systems in urban landscapes, a study has been conducted based on night irrigation and soil moisture measurement by moisture sensors and quality indices of lawn and its impact on water conserving was estimated.

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