Investigating strategies for optimum water usage in green spaces covered with lawn

S.M. Rabbani KheirKhah, F. Kazemi*

Department of Horticulture and Landscape, Faculty of Agriculture, Ferdowsi University of Mashhad, Mashhad, Iran

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Abstract

Water supply of green spaces in arid areas is a major challenge. A high percentage of green spaces create lawns, which are high water consumer landscapes. Due to the environmental, recreational and athletic values of lawns, they are considered as non-removable elements in urban green space development. This paper reviews and discusses strategies for efficient water usage in lawn areas using library study methods. According to the results, first, it was recommended that water demands of turfgrasses are calculated using precise scientific methods. Eleven strategies including selecting appropriate plant species, clipping from appropriate height, removing the thatch layer, using wastewater as an irrigation water source, the use of superabsorbents, application of regulated deficit irrigation, the use of subsurface irrigation systems, replacement of lawns with appropriate ground cover plants, the use of surfactants and other chemicals such as paclobutrazol and endophyte fungi, as individual or combined strategies were suggested for efficient water usage in turfgrass areas. These results, in some cases, can be used as executive guidelines by green space professionals in order to reduce water usage in this sector and in other cases, they can be used as preliminary studies for research in the field of sustainable management of turfgrasses in arid and semi-arid areas.

Keywords: Efficient water usage; Turfgrass; Arid areas; Lawn; Green space

1. Introduction

Urban green spaces are part of open spaces with natural or artificial arenas in the urban area covered by trees, flowers, turfgrasses or other plants (Pasban et al., 2014). The importance of green spaces, such as reduction of air pollutions, sound pollutions, positive impact on human mental health, reduction of violence in societies, mitigating urban heat islands, decreasing urban runoffs by reducing hard surfaces and controlling soil erosion in urban spaces, has been discussed greatly (Ruhani, 1993).

Standard for green spaces per capita in the world is between 5 and 50 m². This standard is defined as 30 m² in Iran. However, none of the large cities of Iran has the possibility to develop green spaces according to the global standards. Shortage of water resources is one of the major limiting factors in developing green spaces in Iran (Ruhollahi et al., 2008). One of the important components forming urban green spaces is turfgrasses. According to the surveys conducted in 1977, turfgrasses have covered more than 20 million hectares of the public lands around the world (sport grounds, parks, etc.) (Ansari, 2012).

Kafi (2003) listed the importance of turfgrasses in human daily life in three aspects: first, its
performance in improving environmental conditions; second, its role in recreational and sport activities, and finally, its ornamental role. However, playing these roles and functions are only achievable if enough water is supplied for lawn cultivation. Water contains an average of 80% of the turfgrass weight; obviously, this amount can vary depending on the type and variety of lawn, lawn planting density and location, and its climate conditions. Stems, leaves and roots in turfgrass species have the maximum amount of water, respectively. Reducing a certain amount of water in different parts of turfgrasses leads to plant wilting and eventual death. Ansari (2012) while explaining the role of water in turfgrass physiology, added that water with carbon dioxide and energy is needed for the photosynthesis processes in lawns. Water is involved as a solvent or catalyst in metabolic reactions of living cells. Specific heat capacity of water in plant cells can help to adjust temperature changes in the protoplasm. This feature in turn leads to the protection of the grass against sudden temperature fluctuations. Water also plays an important role in cells inflammation and leaving the stomatas open, thus gases exchanging. The cellular inflammation can also increase tolerance of grasses to footing.

The amount of water consumption in most lawns is between 25 and 75 mm/day compared to many other plant species that commonly considered high consumption of water. Factors, such as the amount of evaporation and respiration, growth season duration, the grass variety, planting density, footing intensity, soil type, rainfall amount and available are the main factors affecting water consumption of turfgrasses (Alami, 2011; Birad, 1973).

Efficient management is required to ensure high quality turfgrasses. Efficient management of turfgrasses includes adequate and timely irrigation and fertilization, dethatching, and top dressing, among which supplying enough irrigation water is the most important management tool. In Iran, agriculture and green spaces are the major consumers of water resources to the extent that if existing varieties are maintained, about 90% of the consumed water is used in these two sectors and the highest water losses are related to these sectors in Iran (Haghayeghi, 2004). Iran is located in the northern hemisphere between latitudes of 25 and 40 northern degrees and 44 and 63 eastern degrees, and is located in one of the driest regions of the world. Average rainfall in this country is 252 mm which is equivalent to a third of the average world rainfall. This is the reason why about 179 mm (71%) of low rainfall amount in the country is evaporated directly, due to the high evapotranspiration potential in the country (15000 to 20000 mm). Therefore, critical water shortage in this country should be taken into consideration (Ansari, 2012). Some studies have been conducted by previous researchers about efficient water usage in urban landscaping. For example, Safari and Kazemi (2014) examined the effect of using non-living mulches and their environmental benefits, such as water consumption reduction in urban green spaces. In other studies, Kazemi et al. (2005) introduced the concept of xeriscaping and its principles and Kazemi (2014) introduced the concept of water sensitive urban design for efficient management of urban water in order to use them in green spaces. This study follows previous research work by Kazemi et al. (2009a, 2009b, 2010b, 2011) in Australia in relation to this concept. Also, Kazemi and Beecham (2008, 2007) in another article discussed the experiences of Australians and their methods of planning and efficient management of water use in arid regions of this country. The employed strategies in urban areas, included water harvesting, reuse of treated wastewater, drip irrigation, night irrigation, the use of mulch, reduction in planting areas of grass in gardens and green spaces, public education, public participation and the most important factor, is correct choice of appropriate native plants. According to these guidelines, the authors raised guidelines for the efficient use of water in arid regions of Iran. In spite of all these studies conducted so far, yet the optimization of water usage in green spaces especially those covered with lawns face different challenges and require further research work. This article at first briefly explains the methods needed to determine water need in lawns and then discusses and studies the proposed strategies for reducing water consumption in lawn spaces.

2. Materials and Methods

This research was conducted in the format of a library research and it reviews published literatures that have passed the process of refereeing before publishing. Thus, the major studied sources include scientific-research papers and arbitrated journals or books at least in one of the Persian or English languages.
3. Results and Discussion

3.1. Determination of water demand

According to Vaziri et al. (2009), the water requirements to compensate plant evapotranspiration losses in cultivated lands is called water requirement. One of the important steps in proper consumption of water resources used in landscaping is accurate estimates of water required by plants. If this estimation is not correctly conducted, it may cause loss of water, not achieving proper performance and decrease in production potential. It can also make soil resources to be destroyed, because of excessive irrigation. It may also lead to water logging and/or lack of enough leaching and soils salinating, and these will in turn ultimately undermine sustainable development of agriculture and green space (Minayee, 2000). It should be noted that the issue of crop water requirement and irrigation water requirement should not be confused with each other. It should be noted that without calculation of crop water requirements, the estimation of irrigation water requirements will not be possible. Nouri et al. (2013a, 2013b, 2013c) performed extensive studies on the best ways to measure water requirement of public green spaces.

Various methods have been used to determine water requirement of turfgrasses. Rana and Katerji (2000) methods of determining crop water requirements are as follows:
1. The methods for measuring evapotranspiration (ET)
   1.1. Hydrological methods including (1) soil water balance, (2) weight lysimeters
   1.2. Micrometeorological methods including (1) the energy balance and Bowen ratio, (2) streamlined procedures, (3) Eddy covariance
   1.3. Plant physiological methods including (1) sap flow method, (2) room system
2. Methods of estimating evapotranspiration
   2.1. Analytical model of evapotranspiration (Penman-Monteith model),
   2.2. Models based on the product coefficient,
   2.3. Methods based on modeling soil-water balance.

In terms of choosing the best method to estimate grass water requirement, many studies have been conducted. For example, in a study conducted by Rahim (1996), several computational methods for estimating evapotranspiration potential of reference crop were compared with lysimetric method and finally Jensen Hayes’s method was introduced as the most appropriate method (Panahi, 2009). Romero and Duker (2009) in their study declared a common method for measuring evapotranspiration of lawns by using a mini-lysimeter and suggested the calculation of reference evapotranspiration using different Penman equations as the most common measuring method.

Ruhani and Hedayat (2011) calculated and reported water requirement of warm grasses in Zahedan with an average value of 7.63 mm/day by using weight lysimeters. This average value had little difference with evapotranspiration amount of reference grass measured by Penman-Monteith method. Shariati (1994) also studied the amount of turfgrass evapotranspiration as reference crop by lysimeters for four years and reported the amount of 1390 mm for a seven-month period (Sharifi Ashoorabadi et al., 2012). Tovey et al. (1969) in their study measured evapotranspiration of two cultivars of Bermuda grass (Cynodon dactylon) in summer using drainage lysimeters methods. Zhang et al. (2007) measured evapotranspiration of three varieties of cold turfgrasses and three varieties of warm grasses by using lysimetric method (Ruhani and Hedayat, 2011). An experiment was conducted by Atkin et al. (1991) to determine evapotranspiration rate and growth characteristics of 10 genotypes of St. Augustine grass. The result showed that evapotranspiration rate in September 1985 (0.21 inch/day) was lower than the rate in August 1986 and September 1987 (0.51 inch/day), respectively. Evapotranspiration rates in this experiment were estimated by soil–water balance method in controlled room and in a farm. This experiment showed that the effect of variety on plant evapotranspiration rate and leaf expansion in chamber was remarkable.

3.2. Strategies to reduce water consumption of turfgrass species

3.2.1. Selection of appropriate plant species

One of the most effective strategies to reduce water consumption in turfgrass species is to select varieties and cultivars that adapted to climatic conditions of the region (Christians and Engelke, 1994). Some turfgrasses native to arid regions due to their high plant density and drought resistance are appropriate selections as turfgrass species (Saeedipooya, 2014). To reduce water consumption of turfgrasses, selected turfgrasses
should have a strong and long root system to be able to reach deeper penetrated water in the soil.

In terms of plant species diversity to be resistant to drought, Iran has the richest germplasm of the world and Geramineae family in this term has a high diversity. It should be noted that different plant varieties have different water needs. For example, Buffalo grass can tolerate very dry conditions without irrigation, while cool season grasses need significant amount of irrigation to survive (Christians, 2013).

Kim and Brid (1988) examined evapotranspiration rate of a number of warm and cool season grasses. The result showed that the difference in evapotranspiration of different turfgrass species was related to the difference in their morphological characteristics, such as stem density, leaf number per unit area, leaf orientation and vertical development of the leaves. In another experiment conducted, Feldhak et al. (1983) used weight lysimeters to measure evapotranspiration of cool and warm season grasses under different nitrogen fertilization rates and different lawn clipping heights. The results showed that Meryon Kentucky bluegrass cultivars and ryegrass consumed 20% more water than Tifway Bermuda grass and Buffalo grass cultivars as warm season grasses and they had 6% reduced evapotranspiration rate in clay soil.

3.2.3. Removing thatch layer

Thatch layer or straw is the dead or alive parts of the stems, leaves, roots, rhizomes and grass pickets formed between the surface layer of the soil and the surface part of the grasses (Nouri et al., 2009). The layer is formed in grasses with a prostrate growth habit, such as Bermuda grass, St. Augustine, Agrostis, Zoysia and Poa (Fallahian, 2004; Kafi and Kaviani, 2003; Nouri et al., 2009). Of its positive effects, reduced evaporation, reduced sudden changes in soil temperature and increased elasticity of the turf grasses can be noted (Harivandi, 2004; Nouri et al., 2009).

Thatch layer in lawn bed can reduce water use efficiency in a number of ways. This generally acts as a barrier against water penetration in the soil and it can cause an increase in the surface runoff and evaporation. This layer also contributes to the surface rooting of the grass and efficiency of the plant will be decreased when water penetrates deep into the soil. To solve the problems and also to prevent the spread of diseases and insects, operation of aeration and removing the thatch layer can be effective (Nouri et al., 2009). Of the methods to struggle with thatch, the methods of mechanical control increased the activity of the soil microorganisms and proper nutrition with nitrogen fertilizers can be stated (Nouri et al., 2009). Aeration time should be set to avoid stress periods. For cool season grasses, late summer to early fall are recommended as the best time for aeration. Early growth season and before mid-summer is the best time for aeration of warm season grasses.

Schlossberg et al. (2008) stated that by aeration in turfgrasses sensitive to thatch, the problem of water infiltration is partly solved, but it is not an effective method to remove this layer. Nouri Imam Zadeyee et al. (2011) conducted a trial to evaluate the effect of aeration and top dressing on cumulative infiltration and final infiltration rate of the soil on Lolium grass. Treatments consisted of three levels of aeration (without aeration, creating holes in sizes of 5x5 and 5x10) and two levels of top dressing (with or without top dressing). The results showed that aeration treatments with top dressing increased 286% in cumulative infiltration.
and decreased basic infiltration rate as compared to the control treatment. In fact, aeration increases soil permeability and top dressing increases its durability.

3.2.4. Using wastewater

The term wastewater means the output water from any process (Mohammadi et al., without year). This process can be an industrial or refining process. In the world, using alternative water sources for a long time for irrigation of different types of green spaces, like green roofs and vertical gardens, have become very popular (Hassani and Kazemi, 2012a, 2012b; Kazemi et al., 2013; Razzaghamanesh et al., 2014a, 2014b). In fact, waste water is an available source and close to the consumer (Malekian et al., 2009; Saadat et al., 2008), valuable in terms of nutrients needed for plants (Malekian et al., 2009; Saadat et al., 2008; Shooshtarian and Tehranifar, 2011; Soroush et al., 2009), and it is possible to replace it with potable water if its pollutants are controlled efficiently (Bliss et al., 2008; Shooshtarian and Tehranifar, 2011).

The amount of wastewater produced from each liter of drinking water is over 75%. As such considering the high population of citizens in the world and their water consumption, it can be deduced that this water source can be used by proper planning to fit for various purposes (Shooshtarian and Tehranifar, 2011). Since ornamental plants, such as grasses, are not edible plants, the use of wastewater as their irrigation water supply source raises less public concern as compared to using this water source of irrigation for productive plants (Soroush et al., 2009). Wastewater can also provide a large amount of grass requirements to nutrient elements, such as phosphorus, nitrogen, potassium and micronutrients. In addition, physiological characteristics of turfgrasses usually assist them to handle hazardous effects of wastewater (Soroush et al., 2009). In most cases, wastewater after advanced and secondary refining processes is suitable for irrigation of turfgrass (Harivandi, 1982). In some cases, toxicity can be created due to accumulation of elements, like chlorine, boron, copper, cadmium, nickel, and zinc. If irrigated plant with wastewater is turfgrass, then it is more tolerant to toxicity than other plants due to its continuous clipping. However, there are concerns about exposure of people to contaminants when they have direct contact with turfgrass, while there are methods to reduce this concern. In a study, Oron et al. (1999) introduced subsurface drip irrigation system as an alternative to surface drip irrigation system when irrigation was undertaken by wastewater. In this method, biological contaminants on the surface soil and direct contact of people with the contaminants became less. The results of Najafi (2008) showed that firstly, filtration of drip irrigation is significantly effective in reducing biological pollutants. Secondly, the gradual injection of wastewater into the subsurface of the soil through subsurface drip irrigation can be effective in reducing biological pollutants from the soil and plant top tissues.

Soroush et al. (2009) examined the effect of irrigation with wastewater on characteristics of Zoysia grass in various soil textures. The use of effluent increased the height and dry weight of the turfgrass and improved its color. Mortram (2003) in his study conducted on irrigation of lawn with effluent concluded that Festuca and Agrostis grasses showed darker color than the control species at the beginning of effluent application. At the end of the experiment, the height and yield of turfgrasses irrigated with wastewater were significantly more than that in the control plants. However, salinity of the wastewater caused bud burning at the end of the experiment. Malekian et al. (1384), in a trial was administered to evaluate the impact of wastewater on characteristics of Bermuda grass with two irrigation methods (surface and subsurface systems) and two water quality (wastewater and well water). It showed that irrigation with wastewater increased the height, yield and phosphorus and potassium absorption in lawns as compared to well water, while irrigation method had no effect on any of these factors. Therefore, the use of wastewater for irrigation of lawns can be an effective way for consumption of wastewater and most importantly, reduce the consumption of potable water for irrigation of green spaces.
3.2.5. Using superabsorbents

Superabsorbents are substances that will be able to attract large quantities of rainfall and irrigation water for plant use and prevent their non-accessibility due to deep percolation in the soil in dry conditions of the soil. Therefore, it prevents drought stress on plants. Sometimes, these materials absorb water up to 400 times of their weight mass (Moradi et al., 2011). Absorbing water quickly and keeping it by superabsorbents increases the efficiency of water absorption from rainfall and irrigation and it can reduce irrigation intervals (Ellahedadi et al., 2005). The beginning of studies on superabsorbents dates back to 1980. In early 2000, wider research, especially in arid regions of the world, such as Africa, South America, Middle East and some Far East regions was conducted (Sarafrazi et al., 2012).

The advantages of using superabsorbents include increasing productivity coefficient of agricultural water (Sheykh Moradi et al., 2011), stability of soil structure and increasing water infiltration into the soil and reducing soil erosion (Lentz et al., 1998; Sarafrazi et al., 2012), increasing germination strength and plant performance (Jahan et al., 2014), reducing evaporation from the soil surface and increasing cultivation level of crops (Beygi, 2013) and increasing irrigation intervals (Abedi Koohpayee and Asstdkazmi, 2006; Dasht Bozorg et al., 2014; Zanguyinasab et al., 2013). The disadvantages include creating sensitivity and environmental pollution, reducing soil air by filling the empty spaces of the soil (Beygi, 2013) and their high cost.

Sheykh Moradi et al. (2011) conducted a study on sport turfgrasses to evaluate the effect of irrigation round and a superabsorbent polymer on qualitative characteristics of the turfgrasses. The results showed that applying 30 to 35 g superabsorbent together with an irrigation interval of two days preserved the quality characteristics of the lawn appropriately, but with long irrigation intervals, yellowing and wilting appeared in the lawns with no superabsorbents being applied in their media and only treatments in which superabsorbents had been applied obtained their freshness after irrigation.

In another research by Nazarli et al. (2010), the highest amount of superabsorbent was shown to have the best effect in all levels of water stress on characteristics like usable water, weight of thousand seeds, seed performance, morphological characteristics and the chlorophyll amount in sunflower plants. Sarfarazi et al. (2012) performed a test to examine the volume moisture changes of soil and water potential of the soil of turfgrasses by applying different quantities of superabsorbent polymer, potassium amide acrile. The results revealed that in treatments containing polymer, water consumption was saved up to 75% when compared with the control treatments.

Yasuda et al. (1998) found out that zeolite in addition to increasing water-holding capacity, acts as moderator of salinity for plants that are irrigated with saline water, after running an experiment to determine the effect of zeolite on controlling water and soil salinity. A ten-year study on protection of the sloped areas of rocky mountains in America with an annual rainfall of about 500 to 550 mm indicated that superabsorbents could control about 65% erosion level in these areas. These materials were added to the soil in steep area and after establishment of native plants in the area, organic matter content of the soil was increased about 2.3%. Savings in irrigation water of the plants in the region was recorded to be an average of 50% (Karimi et al., 2009). Karimi et al. (2009) examined the effect of superabsorbent (Igeta) on plant growth, wilting condition, possibility of survival, ability of holding and absorbing moisture in the soil, irrigation interval and the amount of consumed water on sunflower in three soil textures of clay, loam and sand. The results show that: (1) adding this material to the soil caused an increase in soil volume and changes in the solid, liquid and gas phases of the soil; (2) uptaking nitrogen, phosphorus and potassium was increased; (3) water holding capacity and available water for plants irrigation interval were increased; (4) wilting time of plants was delayed.

Abedi and Sohrab (2005) studied the effect of four usage levels (2, 4, 6 and 8 g/kg) of Zeolite and Bentonite on three soil types (light, medium and heavy) on moisture characteristics of the soils. The results
showed that the use of these inorganic materials will improve soil structure due to an increased adherence of the soil particles especially in light texture soils. The volume percentage of residual saturation moisture and residual moisture of the soil increased. Alami et al. (2011) also examined the effect of superabsorbent, paclobutrazol and irrigation intervals, in climate conditions of Mashhad, on quantitative and qualitative characteristics of the turfgrass (Lolium perenne 'Barbal'). The results showed that the best density of the turfgrass was achieved when 6 g/kg of superabsorbents was applied. Also, color quality, density and chlorophyll content of the turfgrasses that received superabsorbents were increased to 33, 42 and 48% compared to the control species, respectively. In general, the use of 6 g/kg superabsorbent with paclobutrazol is effective in achieving high quality turfgrass with less water consumption.

Xiubin and Zhanbin (2001) concluded that zeolite in soil can increase soil moisture from 0.4 to 1.8% in very dry conditions and increase it from 5 to 10% in regular conditions. Also, Piper et al. (1982) reported that increasing 10% zeolite to washed sand increased germination and establishment of the turfgrass as compared to using sand as controlled growing medium.

Materials used as soil modifier and those which increased the water holding capacity of the soil, can be divided into the following three groups: (a) plant materials, such as sawdust, wood chips, leaves, peat and mucilage; (b) mineral materials, such as perlite, kaolin, peat, bentonite, diatomite, gypsum leca and zeolite; (c) organic materials such as synthetic mulches and polymers, hydro plus and Igeta.

In most cases, superabsorbent materials last in the soil for other plants between 4 and 6 years. However, in case of turfgrasses, the time is reduced to 2 years due to repeated clipping of the lawn and its high elasticity (Glory, 2011). However, irrigation methods also affect durability of the polymers (Terry and Nelson, 1986). The use of 6 g/m² of polymer potassium acrylamide can reduce water consumption of turfgrass from 15 to 40% (Glory, 2011). Therefore, according to these guidelines and type of the soil and climate of the region, compatible and accessible superabsorbents can be used to guarantee reduction in water consumption of the turfgrasses.

3.2.6. Regulated deficit irrigation

In irrigation management, deficit irrigation is a method by which severe damage cannot happen to the plants as a result of drought stress; some amount of irrigation water can also be saved (Ansari, 2011; Salemi et al., 2006). In conditions when water sources are limited, using less water, reducing irrigation costs, especially in pressurized irrigation systems (costs of investment, maintenance and operation) and also the efficiency of water usage raises should also be taken into consideration (Sepahkhah et al., 2007). In a study by Da Costa and Huang (2004), appropriate use of deficit irrigation reduces the amount of water consumption or irrigation intervals and also led to an increase in the efficiency of water consumption in lawns and a decrease in total water consumption for Agrostis stolonifera, Agrostis capillaries, Agrostis canina in summer months. Irrigation with 60% evapotranspiration rate of the reference plant was not associated with a loss in quality and physiological characteristics of these turfgrasses.

Gybolet et al. (1985) observed that by applying deficit irrigation with 80% rate for reference evapotranspiration of sport turfs, turf quality characteristics were not significantly damaged. Ferry and Butler (1983) in a study on Tall Fescue grass (Festuca arundinacea) observed that when irrigation was applied up to 50% rate of reference evapotranspiration with irrigation interval of two days, a slight reduction was seen in visual quality of lawns. Similarly, in a study by Bastug and Bayoktas (2003), which was undertaken on a mixed turfgrass under different drought stress regimes, it was observed that the color of the turfgrass was not affected by different irrigation regimes. In line with these studies, Alami et al. (2011) studied the irrigation intervals on Lolium perenne. The results showed that an increase in irrigation interval from two days to six days significantly reduced the relative water content of the leaves.
3.2.7. Subsurface irrigation system

Improving irrigation management programs and irrigation systems are the two important factors that have considerable impacts in enhancing the efficiency of water usage in agriculture and green spaces (Najafi, 2007). Currently, sprinkle irrigation at the best case is a usual irrigation system in lawns which has disadvantages, such as high evaporation in arid areas. To overcome this water loss, the method of subsurface irrigation, where the emitters are placed below the soil surface, can be used. The use of subsurface irrigation system as compared to sprinkler irrigation systems has advantages, such as reducing water evaporation from the soil surface and possibility for irrigation with lower quality of water resources (Naseri and Pour Abbas, 2006), and also possibility of irrigation only in root zone. Subsurface irrigation is applied in different plantings, such as vegetables, fruits, green spaces and lawn areas (Naseri and Pour Abbas, 2006). This method was first introduced in California in 1359 (Najafi, 2007). The restriction of roots in the soil surface can be its disadvantage.

3.2.8. Replacing turfgrasses with groundcover plants

Considering that a very large area of the world is located in arid and semiarid regions, meaningful strategies for water efficient landscape design of these areas is essential. The so-called building dry landscape (Xeriscpae) was stated by urban planners in America in 1980s due to shortage of water resources and from that time onward, in many other areas of the world, including Iran, distribution of the concept was increased (Kazemi and Beecham, 2007, 2008; Kazemi et al., 2005). Dry landscaping by definition means a method of landscaping based on seven basic principles; one of its important principles is the selection of plants resistant to drought without the need for regular maintenance. Given that turfgrass species are demanding in terms of maintenance and water needs, their covered area should be minimized in this landscaping method, according to the xeriscape principles (Windust, 1995).

In recent years, groundcover plants in many cases are presented as alternative plants to turfgrasses. These plants have several advantages over turfgrasses: the ability to grow in sloped areas or areas with full shade and high moisture or with very dry soils (Safari and Kazemi, 2014) are some of the advantages. Generally, growth and germination of weeds are less in some of them and others well tolerate irrigation with wastewater (Shooshtarian and Tehranifar, 2010) and they have the ability to grow in areas with saline soils and water resources (Easton and Klindrofar, 2009) and with extreme temperature conditions (Shooshtarian and Tehranifar, 2010) and maybe more important; in some cases, they need less irrigation water (Safari and Kazemi, 2014). Of course, the use of these plants in green spaces as a substitute for turfgrasses had deficiencies, such as less tolerance to footing and elasticity as compared to turfgrass species.

3.2.9. Using surfactants

Water disposal is as a management problem in most soil types. But, so far, little definitive research has been conducted to clarify its effects on lawns. Generally, water disposal of the soil can be attributed to hydrophobic organic coating around soil particles or accumulation of these substances in the soil environment (Kostka, 2000). Sources creating the hydrophobic materials may include accumulation of organic derivatives of plants (material derived from decomposition of the roots, decomposition of plant tissues and root sections), derivatives of waxes or vegetable organic acids, fungal hyphae, or organic acids and polysaccharides. Water disposal occurs in all types of the soil and climatic conditions (Muller and Deurr, 2011). Muller and Deurr (2011) divided the methods to tackle the dangers of water repellency of the soil into two groups: direct and indirect methods. Indirect methods can be used to treat symptoms of the problem, including the use of surfactant changing the soil texture to clay type, aerating the soil and choosing suitable vegetation, while direct methods includes bioremediation methods by using proprietary microorganisms of the soil that can create
rapid degradation conditions for hydrophobic materials. In most regions, to improve the existing soil, sand is used and sand is very susceptible to join to the hydrophobic materials. The soil in these areas usually remains dry and water penetration rate in these areas is low. Therefore, these areas will have a non-wetting character. This character can greatly affect the quality of the turfgrass and playing especially in sport fields. Surfactants are surface active materials which would be able to reduce surface tension of the fluids where they are solved and can increase driving power for absorbance of water by soil through reducing the surface tension of water and surface contact angle between water and the soil (Halt, 2008).

Studies have been conducted on the effect of surfactants in improving soil water repellency and reducing dry spots on the lawn surface. Henley et al. (2007) examined the influence of more than 10 types of wetter materials in 9 different places in turfgrasses of golf lands in USA in the year 2003 to 2004. They concluded that none of these materials had a superior effect over others. Nevertheless, the influence of these materials depends on the climate and the location of their application. In another study, Oostindie et al. (2008) demonstrated that in a sandy soil covered by lawn, after four applications of a surfactant (methyl-capped triblock copolymer), water absorption and moisture in soil surface increased and soil water repellency vanished to 250 mm depth.

Cicer et al. (2000) implemented an experiment in 1996 to 1998 in a sandy soil covered with Cynodon dactylon×Cynodon transvaalensis cv. Tijdwarf. In this experiment, in order to reduce water disposal of the soil and remove dry spots from the water repulse of the soil, a number of formulas were used in each year: AquaGro (AG), Primer (P), Aqueduct (AD)t, ACA 1257, ACA 1313, ACA 1455, ACA 1457, Cascade, LescoFlo NO. 07/05. Generally, using each of these materials led to an increase in the quality of turfgrass and a decrease on dry spots resulted from the hydrophobicity character of the soil.

Thomas and Karcher (2000) used a moisturizing agent Aqueduct (AD) on the ground covered with creeping bentgrass cultivar Crenshaw and measured the soil moisture under the turfgrass. They found an increased infiltration rate on dry spots of the lawn, but the moisture content of the soil did not increase. They justified the findings that moisturizing agent has been absorbed by thatch layer of the turfgrass and resulted in reducing the moisture content in the soil. In warm and dry climate, if the amount of replaced irrigation is 60% of evaporation rate, water repellency of the soil under the turfgrass can be reduced by using liquid or granular moisturizing agents of the soil (Barton and Cohmer, 2001).

The disadvantages of surfactants include that they can be costly (Muller and Dourr, 2011), they have toxicity effects on turfgrasses in some cases (Wallis and Horne, 1992), and they create problems in soil structure (Holt, 2008). However, according to the conducted research, surfactants can be used as important elements to reduce water consumption of lawns.

3.2.10. Using other chemicals

Some anti-transpiration materials (Antitranspiranta) are able to reduce water consumption by reducing the plant transpiration. Sometimes, this reduction is done by creating a temporary coating on the outer surface of the plant. Sometimes, these materials enforce their anti-transpiration effect through biochemical and physiological changes on the plants (Bayat et al., 2011; Razavizadeh and AmooBeygi, 2014). Among these materials is paclobutrazol, which is a plant growth hormone and belongs to azoles group (Alyani et al., 2014). This substance may cause resistance to drought, salinity, cold, heat, air pollution and flooding conditions (Bayat et al., 2011; Rademacher, 1995; Razavizadeh and Amoo Beigi, 2014) and create the effect of its drought resistance by reducing transpiration, height (Bayat et al., 2011; Nishizawa, 1993; Razavizadeh and AmooBeygi, 2014), dry matter, leaf area (Nishizawa, 1993; Razavizadeh and Amoo Beygi, 2014), increased root growth (Bayat et al., 2011) and increased stomata resistance (Nishizawa, 1993; Razavizadeh and Amoo Beygi, 2014). A general method of its application is spraying solution and application in soil (Shakeri et al., 2010;
Alayni et al., 2014). A research was performed by Aliani et al. (2014) in Karaj in order to investigate the effect of paclobutrazol on lavender under dry conditions. It showed that by applying 250 mg/L of paclobutrazol in soil prevents water losses from the soil and make it available for plants. Also, other studies showed that peach seedlings treated with paclobutrazol reduced their dry and fresh weight and consumed less water in greenhouse conditions (Arzani and Roosta, 2004; Alayni et al., 2014). It seems that the impact of this material on trees and shrubs is more than that in turfgrasses. This might be because this substance which is associated with turfgrass tissues is continuously harvested during the growing season by clipping the lawn (Christians, 2013). However, despite the benefits associate with applying such materials via reducing water consumption through reduction on evapotranspiration, it seems that since one of the benefits of transpiration is cooling the plants, applying these materials which are followed by reducing evapotranspiration can increase tip burning potential in turfgrasses especially during warm months of summer.

Plant growth regulators also are able to reduce water consumption of plants. As an example, it has been seen that materials like Flureprimidole (Canlex) and Mephloydad (Ambark) reduced water consumptions as much as 20 to 30% in St. Agustine and Bermuda grass (Beard, 1985).

3.2.1. Using endophyte fungi

Endophytic fungi belonging to the genus Neotyphodium have a symbiotic relationship with most cold grasses (Khayyam Nekooy et al., 2010; Parsaian et al., 2007). These fungi are seed-generating and transmitted to the next generation (Bacon and White, 1994). In a study, the fungus was identified in Fescue plants native to Iran (Khayyam Nekooyi, 2001). This fungus has many benefits for its host plant which include resistance to insects, bacteria, viruses and nematodes (Parsaian et al., 2007; Malinowski and Blusky, 2000; Khayyam Nekooyi et al., 2010), resistance to environmental stresses, like drought and cold (Baken and White, 1994; Robert et al., 2005, Parsaian et al., 2007; Khayyam Nekooyi et al., 2010), resistance in dealing with toxic elements and acidity changes and increase in plant performance (Parsaian et al., 2007).

In terms of resistance to drought, this fungus can act by mechanisms like rapid stomata closure, osmotic pressure adjustment (Malinowski and Blusky, 2000; Khayyam Nekooyi et al., 2010), increased stomata resistance, rolling of the leaves, rapid growth, increasing effective root depth (Parsaian et al., 2007; Robert et al., 2005; Khayyam Nekooyi et al., 2010), increase resistance of the grass to drought and less irrigation.

Other research in which Khayyam Nekooyi et al. (2010) studied tolerance of long Fescue to drought in the presence of endophyte fungus also resulted to the similar conclusions in that this fungus increased drought resistance of the lawn and treated turfgrasses with these fungi had better growth than the non-treated control turfgrasses in drought stress conditions.

4. Conclusion

Due to the scarcity of water resources in arid countries and high requirement of the turfgrasses to these resources, achieving strategies for efficient water usage is essential for lawn scaping. This achievement in the first step depends on accurate determination of water needs of the turfgrasses. Such method can be selected with regard to available facilities and the level of the accuracy required.

Apart from the need for determination of water requirement of the turfgrasses, different strategies may affect water required in lawns which can be used as single or combined strategies. In some cases where the use of turfgrasses is necessary, the first and most important strategy in the planning stage is choosing suitable species that requires less water and more resistance to drought. Some management strategies, such as clipping of the lawn from an appropriate height and managing thatch layer are relatively low cost and environmentally friendly water efficient management strategies in lawns. In soils which are covered with turfgrasses for a long time and usually are faced with water penetration issues due to accumulation of their root systems or having hydrophobic organics in the soil, using relatively low-cost surfactants from locally available
materials can be a useful water efficient strategy to grow lawns. Among these materials, zeolite and bentonite from mineral groups and potassium acrylamide from synthetic groups can be useful. Deficit irrigation practices, as a single strategy or together with the use of superabsorbents in the soil can result in lower water consumption and produce better quality turfgrasses. Finally, using anti-transpiration materials or endophytic fungi that can reduce transpiration in plants are useful strategies for maintaining quality lawns with less water. It should be noted that all the afore-mentioned strategies together with the use of alternative water resources other than potable water for irrigating of lawns should be considered as highly important. Tolerant grass species to wastewater should be determined and strategies should be applied for using subsurface irrigation methods with sewage for optimal water resources usage and maintaining public health. In places where there is no need for the characteristic of turfgrass elasticity, lower water consuming plants with similar applications such as ground cover plant species should be planted as alternatives. Such plants, in some cases, in addition to consuming less water can provide more aesthetics and environmental benefits in design and construction of urban green spaces.

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