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Examining performances of organic and inorganic mulches and cover plants for sustainable green space development in arid cities

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Abstract

Green space is one of the important infrastructures for keeping natural life and sustainability in modern urbanism and it provides excellent recreational opportunities for the people in the society. However, there are limiting factors in green space development, especially in arid regions, including extreme weather and soil temperatures, low average rainfall, drought, and high potential for evapotranspiration. Therefore, sustainable green space development, especially in these regions, should seek strategies and landscape materials to tackle these limitations. Some green space materials, which have been argued to address such limitations, are mulches; but still potentials of these materials in urban green space development have not been well discussed. This study reviewed scientific literature in order to discuss how non-living mulches and cover plants as living mulches can assist in the development of green spaces in arid regions. It aimed to introduce mulches and cover plants and compare their environmental, ecological, functional, and aesthetic potentials. According to the results, cover plants and non-living mulches can maintain visual aesthetics while they can also have environmental benefits, such as reducing water consumption, weeds and soil erosion as well as adjusting soil moisture and temperature in urban green spaces. High diversity of cover plants is one of the most important and practical features for green space development. This paper also identified that, despite significant benefits listed for using these materials in urban green space, their application in green space design and construction of many countries, such as Iran, is still less considered.

Keywords: Cover plant; Mulch; Organic; Sustainable; Urban green space

1. Introduction

Green spaces are attractive and suitable places for social interactions and excellent recreational opportunities for a variety of people and ages in the society (Hatami Nejad *et al*., 2011). They are also one of the key factors for maintaining natural life in modern urbanism (Mortezai Nejad and Etemadi, 2006). "Urban green spaces are defined as parts of urban open spaces that, in their natural or often artificial areas, are covered by trees, shrubs, flowers, turfgrasses, and cover plants. These spaces are maintained or constructed based on people's supervision and management. They are conserved, maintained, or constructed according to related criteria, rules, and expertise to improve environmental conditions, enhance natural habitats, and improve citizens' welfare" (Majnoonian, 1995). Expanded urbanization and population growth increases human need for natural and green environments in urban spaces; hence, the need to construct urban parks, gardens, and green spaces. Current urban environments in the world are faced with many problems, such as air and water pollution, noise pollution, water shortage, and increase of mental and psychological problems in people. Constructing green spaces is a

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suitable solution to solve these problems (Hatami Nejad *et al*., 2011).

Water and soil are important limited resources in green space development (Jian Borjaki *et al*., 2007). High soil erosion (Mahmood Abadi and Arab Khedri, 2011) and water shortage resulting from population growth (Quist *et al*., 1999) in arid cities of the world and its negative impact on natural resources and green space development emphasizes the need for further research and practical work to solve these issues (Mahmood Abadi and Arab Khedri, 2011). Erosion is one of the most important factors in land degradation which causes reduction of water holding capacity of the soil and destabilization of soil structure, especially in arid and semi-arid regions (Shahab Arkhazlu *et al*., 2011). Low average precipitations (Mortzayi Nejad and Etemadi, 2006), over-exploitation of groundwater (Naderianfar *et al*., 2011; Pakdel, 2010), drought, high temperature, and soil salinity are some of the problems which can be seen in establishing green space sections, such as turfgrasses in arid regions (Bowker and Edinger, 1989; Ansari and Azimi, 2011; Roohollahi *et al*., 1999). However, turfgrass development requires high maintenance practices, such as proper fertilization, ideal irrigation, and clipping, which require resources (Bowker and Edinger, 1989). Especially, water need of turfgrasses in arid regions with high evapotranspiration rates is a significant burden for development (Ansari and Azimi, 2011). Therefore, selecting appropriate low water-consuming plants or other landscape materials to be replaced with lawns is critical in creating and maintaining sustainable green spaces (Jian Borjaki *et al*., 2007).

Achieving sustainable green spaces also depends on efficient management. One of the requirements for an efficient green space management is weeds control. Weeds directly compete for water, nutrients, and light with main plants, reduce the quality of green space, disturb its beauty, and increase consumption of resources. Weeds cause problems by making green spaces desirable for rodents, create problems in pruning ornamental plants, slow down movement of air, increase chilling injury, and eventually, create an ugly scene for the green space (Majni *et al*., 2011). In a sustainable weed management system, the best solution is to reduce using chemicals by incorporating mechanical and biological methods and, even better, to prevent growth of weeds using sustainable strategies (Ebrahimpur and Yusefi, 2012). One suggested solution is using mulches and cover plants to control weed growth. In addition to the important effects of green spaces in environmental sustainability (Golchin *et al*., 2012), their psychological effects, which are mainly related to their aesthetic values, must also be considered (Mofidi Shemirani and Alavi Zadeh, 2010). It is argued that people do not feel welcome in a uniform environment and one of the most important principles in green space design with visual aesthetic is diversity (Motevali, 2010); using a variety of cover plants and other covering materials, such as mulches, can create diversity in green spaces. Low maintenance of cover plants and non-living mulches facilitate their usage and help in creating diversity in green space development (Bowker and Edinger, 1989). Diversity has an important role in creating positive perception in people, so that by creating diversity in green areas, people's satisfaction can be met.

In order to move toward sustainability in urban green space development, we have to seek strategies and green space materials that could promise low input, low resources, and low maintenance green spaces with largest environmental and aesthetic benefits. Having this major goal in mind, this study aimed to review the role of cover plants and organic and inorganic mulches as relatively newly introduced materials in urban green space development. These roles are categorized into three aspects of environmental, aesthetic, and functional performances in this manuscript.

2. Materials and Methods

This research was performed in form of a library study and by analytical review of published literature that were refereed before being published. Therefore, the main examined sources were books, MSc and PhD theses, and research articles published in journals in Persian or English languages.

3. Findings and Discussion

3.1. Definitions

The word 'Mulch' is originated from the German word 'Molsh', meaning soft (Chalker-Scott, 2007). It is defined as any of the natural or synthetic substances that cover the soil surface in green spaces (Brown, 1996; Chalker-Scott, 2007), it protects and promotes soil quality (Brown, 1996) and generally has a thickness between 1-4 inches

(2.54-10.16 cm) (Bowker and Edinger, 1989). Mulches are divided into two important categories: organic and inorganic (Singer and Martin, 2008; Skroch *et al*., 1992; Duryea *et al*., 1999; Steward *et al*., 2003). Organic mulches include wood products, such as shredded pine bark (Bowker and Edinger, 1989; Duryea *et al*., 1999; Skroch *et al*., 1992; Stinson *et al*., 1990; Iies and Dosmann, 1999), bark pieces of forest trees (Iies and Dosmann, 1999; Stinson *et al*., 1990; Skroch *et al*., 1992), shredded cedar bark (Bowker and Edinger, 1989; Stinson *et al*., 1990), recycled wood pallets, and wood debris of cacao tree (Iies and Dosmann, 1999; Steward *et al*., 2003). Also sawdust, which has a fine texture and helps soil nitrogen to be decomposed, (Bowker and Edinger, 1989), pine straw and barley straw (Steward *et al*., 2003), and animal manures, that are consumed as compost because their fresh form can cause burning (Bowker and Edinger, 1989), are in the category of organic mulches. Agricultural products, such as corn woods, mushroom compost, shells of different nut products and cotton seeds (Bowker and Edinger, 1989), needle-shaped leaves of pine (Duryea *et al*., 1999; Brown, 1996; Iies and Dosmann, 1999) with nice appearance and good permeability, which have been found to reduce soil PH (Bowker and Edinger, 1989), and clippings of turfgrasses (Steward *et al*., 2003; Stinson *et al*., 1990) can also be used as organic mulches.

Inorganic mulches can include pieces of brick (Steward *et al*., 2003; Iies and Dosmann, 1999), pieces of rubber (Steward *et al*., 2003), decomposed granite (Singer and Martin, 2008), various stones (Duryea *et al*., 1999; Iies and Dosmann, 1999), sand (Duryea *et al*., 1999), polyethylene (Duryea *et al*., 1999; Iies and Dosmann, 1999), and pea-shaped gravel (Iies and Dosmann, 1999). In choosing mulches, some factors should be considered, such as cost of their usage, aesthetic appearance, compatibility with the environment (Litzow and Pellet, 1983), ability to maintain color (Stinson *et al*., 1990; Duryea *et al*., 1999), and speed of decomposition (Stinson *et al*., 1990).

Cover plants are plants with a high diversity and expansion capability in various locations and climates (Bowker and Edinger, 1989; Mackenaize, 2003) and rapid growth, which have maximum height of one meter (Shooshtarian and Tehranifar, 2009). This group of plants are expanded from creeping wooden shrubs to herbacious perennials and some bulb-like plants (Ghasemi Qahsareh and Kafi, 2010).

3.2. Environmental and ecological performances

Investigated research has suggested the following environmental advantages for mulches and cover plants:

3.2.1. Water saving

If a bare soil is exposed to heat, wind, and other environmental factors, water in the soil reduces through evaporation. Selecting appropriate mulches can significantly reduce irrigation frequency in green spaces (Chalker-Scott, 2007). Mulches can keep moisture and water retention in the root zone (Litzow and Pellet, 1983; Smith *et al*., 1997; Koshki and Jocobi, 2004; Duryea *et al*., 1999); therefore, the water can be available for a longer time for the plants (Bowker and Edinger, 1989; Pakdel, 2010). The rate of evaporation from a soil surface covered with mulches compared to a bare soil is less (Singer and Martin, 2008; Steward *et al*, 2003; Iies and Dosmann, 1999; Duryea *et al*., 1999). This is a good feature for keeping the soil surface cooler and creating less urban heat island effects in hot and dry climates (Singer and Martin, 2008). Also, penetration of water into the underlying layers of the soil can be facilitated in such soils (Bowker and Edinger, 1989; Skroch *et al*., 1992).

In some cases, when a plastic mulch is used, water movement between the mulch and the land surface and subsequently re-irrigation process is faced with some restrictions. In contrast, using sand and rock mulches, animal manure, and a wide range of plant materials as mulches does not hinder penetration of water into the soil and also improves the ability of the soil to retain water (Chalker-Scott, 2007; Balvinder *et al*., 1988; Martin and Poultney, 1992; Kraus, 1998). Using species of *Andropogon* sp., *Spirae apubescens*, and black acacia (*Robinia pseudoacacia*) as living mulches would lead to a better and increased penetration of water into the soil (Wang *et al*., 2013). Using the mulch of rice straw, the yield of crop showed a 10% increase and water use efficiency increased to 100% (Bunna *et al*., 2011). Zhang *et al*. (2013) concluded that the use of wide plastic mulches retained 12% more moisture than using narrow plastic mulches. The difference in soil moisture between these two types of mulch was mainly 15.96 mm, which was shown in soil depth of 60 cm. Using plastic mulch in Broccoli increased water use efficiency from 1.4 to 4.8 kg/cm^3. The use of plastic mulch increased water content of the soil at 5 cm to 4.7% in clay soils, 3.1% in loamy soils, and 0.8-1.8% in sandy soils (Ramakrishna *et al*., 2006). Retaining soil moisture by using mulch of wheat straw was 10-20% higher than retaining soil moisture in mulch of black polyethylene (Ghosh *et al*., 2006). In Singer and Martin's experiments (2008), it was identified that the loss of water in bare soils was approximately 70 mm. When the soil was covered with organic mulch of non-composted wastes of trees, this number was only 31 mm. In another test, the highest amount of soil moisture was recorded in a soil covered with wood chips and bark of Giant trees and the least amount of moisture was recorded in surface of bare soil (Litzow and Pellett, 1983).

It is possible to cultivate cover plants with ornamental trees and shrubs and, in fact, the roots of cover plants can assist in increasing soil porosity and its organic materials. Therefore, ornamental trees and shrubs can have deeper root growth and their access to the resources become easier (Mackenaize, 2003). Cover plants, compared to lawns, usually need less water and less care after planting (Bowker and Edinger, 1989; Mackenaize, 2003; Shooshtarian and Tehranifar, 2009; Ghasemi Qahsareh and Kafi, 2010). In contrast, lawns usually need more water and difficult maintenance regimes, which are fundamental limitations in green space development in arid regions. Cover plants can be applied in areas where turfgrasses cannot grow or cannot be easily maintained (Shooshtarian and Tehranifar, 2009). In fact, one of the practical applications of cover plants is replacing lawn with them (Ghasemi Qahsareh and Kafi, 2010). One study found that water need of Frankenia was 21% of the total water need for sport turfgrass; this is a positive feature in low-water regions. In very shady places, turfgrasses cannot grow well due to the lack of enough sunlight and presence of high competitions for obtaining food and water. In such cases, using cover plants like *Hedera helix* is possible. In other cases, using cover plants in places with extreme moisture conditions (very humid or very drought) or in steep slopes is more economic and suitable. Keeping lawn in these places is almost impossible (Shooshtarian and Tehranifar, 2011).

Table 1. Effect of 8 mulch treatments compared to non-mulch treatment as control on soil temperature and moisture (Jeffery *et al*., 1999)

Treatment	Temperature[z] (°C)	Miosture[y] (%)
Control	9.3 [a]	19 [d]
Pea gravel	27.6 [b]	31[ab]
Crushed brick	26.2 [c]	30 [bc]
Carmel	26.2 [c]	29 [c]
River rock	25.2 [d]	29 [c]
Lava rock	24.5 [d]	30 [bc]
Shredded bark	23.6 [e]	31 [ab]
Wood chip	23.3 [e]	32 [a]
Screened pine	23.3 [e]	32 [a]

Z: Soil temperature measured at 10 cm (4 in.) depth, between 2:00 and 4:00 P.M.
Y: Soil moisture measured at 6 cm (2.4 in.) depth, between 2:00 and 4:00 P.M.

3.2.2. Reducing weeds

Presence of weeds in bare soils uncovered with vegetation and mulches can increase evapotranspiration by 25% during summer days (Chalker-Scott, 2007). Organic mulches suppress weeds and prevent their seed germination by burying the seeds (Bowker and Edinger, 1989; Brown, 1996; smith *et al*., 1997; Skroch *et al*., 1992; Koshki and Jocobi, 2004; Duryea *et al*., 1999; Pakdel, 2010), and because of their loose texture, if any weed grows, pulling it out is easy (Bowker and Edinger, 1989). Removing weeds can take place with different strategies, including increasing useful microorganisms of the soil, allelopathy, making competition over resources (Griffiths and Fairhurst, 2003), and preventing their seed germination by plastic mulches. Some mulches absorb suitable wavelengths for germination and growth and thereby reduce percentage of weeds. Also, depending on the amount of light absorbed by the plastic and the amount of heat reflection preserved, they are able to increase or decrease soil temperature (Chalker-Scott, 2007). An influential factor in removal of weeds is depth of the mulch (Rokich *et al*., 2002). Gravel with a thickness of 4 cm is efficient in preventing growth of the weeds (Winkel *et al*., 1995). If mulches possess coarse textures, low thickness, and low nutrients, they can be more effective in controlling weeds; and in some cases they are even more effective than applying herbicides (Chalker-Scott, 2007; Forment *et al*., 2000). Using organic mulches can control weeds by 50%. Organic mulches and polypropylene are effective in controlling perennial herbaceous weeds and are effective in reducing maintenance costs of green spaces (Skroch *et al*., 1992). Living mulches or cover plants, such as vetch (*Vicia villosa*), clover (*Trifolium subterraneum*), and oat (*Avena sative*), can control weeds to about 80% (Campiglia *et al*., 2010). In addition to these practical applications, mulches usually have a nice appearance and can add to the beauty of the landscape (Chalker-Scott, 2007; Pakdel, 2010). Cover plants also prevent growth of weeds, sometimes through their allelopathic substances (Shooshtarian and Tehranifar, 2009); for example, some plants such as *Valeriana officinalis* has an active ingredient with capability to remove weeds (Shooshtarian and Tehranifar, 2011). Such method for removing weeds can decrease using chemical herbicides; hence, reduce environmental pollutions.

3.2.3. Moderating soil temperature

A variety of organic and inorganic mulches can assist in balancing temperature in root zone of the plants in green spaces (Bowker and Edinger, 1989; Singer and Martin, 2008; Brown, 1996; Stinson *et al*., 1990; Koshki and Jocobi, 2004; Steward *et al*., 2003). According to Singer and Martin (2008), the temperature of the soil in depth of 10 cm below organic mulches is approximately 2.5 °C lower than the temperature in soil depth of 10 cm below inorganic non-living mulches. Organic mulches prevent diffusing the heat energy into the soil and this will be followed by soil temperature decrease in green spaces (Singer and Martin, 2008). The use of plastic mulches in agriculture is not popular due to increasing the soil temperature (Bonachela *et al*., 2012; Ghosh *et al*., 2066; Moreno and Moreno, 2008; Diaz-Perez, 2009). Using polyethylene mulches, soil temperature increases about 6 °C and 4 °C in depths of 5 and 10 cm, respectively, while a mulch of wheat straw increases soil temperature for about 2.3 °C (Ramakrishna *et al*., 2006).

In another study, the soil temperature increased about 4 to 5 °C using a polyethylene mulch (Ghosh *et al*., 2006). Soil temperature by using starch-based biodegradable mulch was recorded 14.8-26.6, while this temperature in bare soil was 13.8-23.6 (Moreno and Moreno, 2008). Singer and Martin (2008) found that when decomposed granite is used as an inorganic mulch in green spaces, the temperature in 5 cm depth of the soil surface is increased to more than 40 °C. In contrast, using an organic mulch of ponderosa pine residue (PPR) and shredded non-composted landscape tree trimmings in green spaces averagely decreased soil temperature to 13-22 °C, compared to a soil covered with screened decomposing granite. Also, in soil depth of 30 cm covered with screened decomposing granite, the temperature was 8 °C warmer than the soil covered with organic mulches, while in the same soil depth not covered with any mulch, the temperature was 10 °C warmer than the same soil cover. The average temperature of the soil covered with inorganic mulches was recorded between 32-28 °C in this experiment. In another experiment, when a mulch of black polyethylene was used for trees, it increased the soil temperature in the beginning of the Spring and was simulated root growth and initiated flowering and leaf development more than that in trees for which mulches were not used (Litzow and Pellett, 1983).

Organic mulches reduced highest daily temperature of the soil surface to 2.2-3.3 °C and increased minimum daily temperatures of it to 1.1-2.2 °C (Skroch *et al*., 1992). In a test in where inorganic mulches were used, the temperature was raised and humidity levels were declined. It also led to an increase in maple trees growth (*Acer rubrum* L.) and creation of larger stems in these trees. The average temperature in plots using inorganic and organic mulches was 25.9 °C and 23.4 °C, respectively (Iies and Dosmann, 1999).

3.2.4. Changing soil properties

Soil compaction is common in urban areas. In this regard, some reasons, such as compression caused by vehicles' traffic is obvious, but compression by precipitation, which is due to lack of protection of the soil, is not much obvious (Chalker-Scott, 2007). Mulches decrease pressure from precipitation or irrigation, and therefore, decrease damage to the soil (Bowker and Edinger, 1989; Lal, 1984). Straw mulch with a thickness of 2.54 cm (1 inch) is effective in erosion control by preventing the soil compaction caused by rain drops (Borst and Woodburn, 1942). Reducing soil erosion (Bowker and Edinger, 1989; Lal, 1984) and improving soil structure (Lal, 1984; Brown, 1996) are some of the benefits of mulches. Followed by decomposition of organic mulches, the soil properties would improve (Bowker and Edinger, 1989).

Mulches impact on soil pH as well. Oak leaves, pine leaves, wood chips, and bark chips reduce soil pH (Iies and dosmann, 1999; Stinson *et al*., 1990). Accumulation of produced organic acids by decomposing none-living mulches after washing into the land decreases soil pH (Iies and Dosmonn, 1999). The pH increases by using bark of forest trees (Stinson *et al*., 1990). This increase may be due to temporary ammonium ion production as a result of disintegration of organic materials. In fact, oxidization of these ions and converting them into nitrate causes a decrease in soil pH (Iies and Dosmonn, 1999).

Mulches are able to improve soil conditions in long term. Using mulch of bark chips of forest trees during 8 years increased porosity and reduced bulk density of the soil (Oliveira and Merwin, 2001). If animal and green manures are used as mulches, they release more nutrients than other mulches into the soil (straw, bark, and wood chips) and often perform better than inorganic fertilizers (Downer and Hodel, 2001; Pickering and Shepherd, 2000). The organic mulches reduce toxic effects of salt on plant growth and enhance desalting actively. This is probably because they are able to band to ions (Landis, 1988; Chalker-scott, 2007), and also they are effective in eliminating heavy metals from soils of gardens and green spaces. Lead and cadmium, which are pollutants in urban areas, are often able to be removed from the soil by the leaves of eucalyptus, pine, poplar, and crock cedar (Salim and El-Halawa, 2002).

Mixture of compost and wood chips is effective in removing copper through converting it to the lowest toxicity forms of copper (Kiikkilä *et al*., 2002). Cover plants, as well as mulches, prevent soil erosion (Bowker and Edinger, 1989; Mackenaize, 2003) (Ghasemi Qahsareh and Kafi, 2010). By replacing lawn with cover plants and subsequent lack of using lawn mowers, soil compression will decrease and also trunk of trees and shrubs in green spaces remain immune to mechanical damages of lawn machineries (Mackenaize, 2003).

3.2.5. Reducing pollutants

Some cover plants are able to accumulate sulfur in their shoots in places where rainfall intervals are long and air pollution and dusts in urban green spaces are dominant (Mackenaize, 2003). Honey suckle (*Lonicera japonica*) and Cotoneaster (*Cotoneaster* sp.) have also the ability to tolerate low temperatures due to possessing deep root systems. *Pleurozium schreberi* has been applied as a cover plant in order to detect atmospheric NOx biologically and stabilize nitrogen. Nitrogen oxides (NOx) are among the key phytotoxic components in many urban areas and contribute to acidification and eutrophication of ecosystems (Mannienen *et al*., 2013).

3.2.6. Cover plants and resistance to environmental stresses

In green space plants, maintaining visual aesthetics is more important than their growth, even under stress conditions (Niu and Cabrera, 2010). Juniper (*Juniperus chinensis*) has a high resistance to salinity (Fox *et al*., 2005). Plants such as yarrow (*Achillea millefolium*), gaillardia (*Gaillardia aristata*), *Lantana* x *hybrida*, honeysuckle (*Lonicera japonica*), and rosemary (*Rosmarinus oficinalis)*, when they were irrigated with a water source with a salinity 4.5 ds/m, compared with the conditions where they were not affected by salinity, kept an acceptable beauty (Niu *et al*., 2007). In an experiment, irrigating *Leucanthemum* x *superbum*, *Mirabilis multiflora*, and *Lavandula angustifolia* with solution containing $CaCl_2$ and NaCl with ratio 2 to 1, it was found that the three plants had the highest tolerance to the solution and they maintained a good quality by the end of the experiment (Zollinger *et al*., 2007). Niu and Rodriguez (2006) found that yarrow (*Achillea milefolium*), gaillardia (*Gaillardia aristata*), and sage (*Salvia coccinea*), when they were placed under saline irrigation water in greenhouse conditions, showed a relatively higher tolerance to salinity 4 ds/m than the other species and, therefore, they kept an acceptable visual quality and could be used in green spaces under saline conditions. *Lupinus texensis* plant showed an acceptable visual beauty when salinity increased to 7 ds/m despite its shoot growth reduction (Niu *et al*., 2007). Climber plants and bedding flowers are widely used in landscaping. Salinity threshold of irrigation water until slowdown point of the growth was 4 ds/m for *Angelonia angustifolia* and 4-51 ds/m for *Helenium amarum*, *Helichrysum petiolatum*, and *Plumbago auriculata*. The highest concentration of sodium (Na) in two plants, licorice (*Helichrysum petiolatum*) and plumbago (*Plumbago auriculata*), was 10 to 30 g/kg dry weight (Niu *et al*., 2010).

3.2.7. Allelopathic effects

It has been recognized that some mulches produce allopathic effects. These materials prevent germination and growth of plants in green spaces. The reason for this feature is presence of hydroxyl aromatic compounds (Duryea *et al*., 1999). Cover plants sometimes also prevent germination of weed seeds because they produce allelopathic materials and prevent reaching light into the soil (Shooshtarian and Tehranifar, 2009). Chemical inhibitors are transferred from plants to the environment by a few different methods, such as evaporation from their leaf texture, leaching non-evaporable materials from their branches and leaves by raining, leakage from living roots, and decomposing the residual materials by soil microorganisms (Duryea *et al*., 1999; Shooshtarian and Tehranifar, 2009).

3.2.8. Effect on plants' growth

Mulches can cause rapid establishment of plant roots in the soil and subsequently faster growth of plants (Bowker and Edinger, 1989; Smith *et al*., 1997; Koshki and Jocobi, 2004; Skroch *et al*., 1992; Brown, 1996). Mulches improve germination, root establishment, and survival of transplanted plants. The type of mulches influence on how roots form; for example, sheet mulches, which create an obstacle for water and air penetration under the soil, encourage root growth in upper part of the mulch and this can cause a damage to the plants if the mulch is removed. Development and density of the root system is more, using organic mulches as compared to bare soil and plastic mulches (Chalker-Scott, 2007). Mulches should be placed at a distance of 15 cm from the trunk of the trees. Paying no attention to this point can damage the trunk by expanding some diseases. In some cases, a small gap between the trunk and the mulch create problems in respiration of cambium and phloem cells and other living cells of the trunk and can limit exchanges of oxygen and carbon dioxide between the trunk and the atmosphere (Koski and Jacobi, 2004). Using plastic mulches to control weed expansion in agricultural crops (Shogren and Rousseau, 2005; Ramakrishna *et al*., 2006, 2003) and keeping soil moisture (Zhang *et al*., 2013; Kashi *et al*., 2003) by mulches are widely discussed. These kinds of mulches are effective in increasing crops' height, growth, flowering (Ramakrishna et al, 2006), and its total performance (Kashi *et al*., 2003; Mukherjee *et al*., 2010). Living mulch of white clover (*Trifolium repens*) increases activity of soil microorganisms (Nakamoto and Tsukamoto, 2006). Grassy mulches can better establish spruce trees and improve their soil conditions (Fang *et al*., 2008). Winter cover crops that can be converted into mulches in Spring include vetch (*Vicia villosa*), clover (*Trifolium subterraneum*), and oat (*Avena sativa*) (Campiglia *et al*., 2010). Brown *et al*. (1996) investigated the effect of mulch of municipal solid waste (MSW), needle-shaped leaves of pine, leaves of cypress, and eucalyptus on plant growth and they found that the best growth of the plant (*Hibiscus* sp.) was performed in cedar mulch and subsidence rate of needle-shaped leaves of pine and cedar were recorded 72% and 20%, respectively.

3.3 Aesthetic and functional applications

An important factor in beauty of a mulch is maintaining its color (Stinson *et al*., 1990; Duryea *et al*., 1999). In a recent study on some tested organic mulches, it was found that most color changes happened in clipping lawn when it was used as a mulch. This mulch is dried and decomposed quickly, and its subsidence takes place sooner than pine barks, cedar leaves, pine straws, wood chips, hardwood and oak leaves as mulches. The slightest color changes were observed in wood chips of forest trees, pine straws, branches, and serving pieces (Stinson *et al*., 1990). Durability of mulches is an important factor in their selection and application in green spaces (Lal, 1984). Factors that effect on decomposition rate of mulches include lignin to nitrogen ratio, nutrient composition of mulches, and their breathing rate. The more the amount of lignin is, the lower mulch decomposition rate will be. Cypress mulch consisted of 55% carbohydrate after six months of the experiment which indicates its slow breaking down.

Nutrient compositions of mulches are considered as a food sources for microorganisms (Chalker-Scott, 2007) and, subsequently, decomposition is an important factor in enhancing decomposition (Duryea *et al*., 1999). In a comparison among six types of mulches in green spaces, it was found that after one year from the start of the test, decomposition in an eucalyptus mulch and utility trimming mulch (GRU) (a combination of pruned parts of some trees including oak, cherry, pine, and cypress in less levels) took place to 21% and 32%, respectively, whereas other mulches were decomposed only 3% to 7%. Decomposition rate has a negative correlation with lignin to nitrogen ratio. Lignin to nitrogen ratio was lower in these two non-living mulches. Also, respiratory rate is associated with decomposition rate. On these two mulches, the rate of respiration in winter was more than that in other mulches. The lowest rate of decomposition was recorded in cypress mulch because of less available nutrients and less active microorganisms on it. This mulch can retain its color during a year compared to other mulches. The higher the decay rate of a mulch is, the more the need for its replacement will be. Subsidence rates varied among the non-living mulches. Subsidence rate of non-living pine straw was recorded from 9 cm to 4 cm, while the subsidence rate in other non-living mulches was recorded only 2 cm (Duryea *et al*., 1999). The mulches with high speed decomposition included harvested lawn and leaves and residues of local products, such as mulch with medium degradation rate: straw, hay, coconut coir fibers, such as hemp, and mulch with low decomposition speed, wood residues, such as sawdust and bark and hard and soft wood chips (Chalker-Scott, 2007).

In an environment where color diversity is required, cover plants are suitable options (Shooshtarian and Tehranifar, 2009). From perceptual aspects, cover plants have artistic characteristics in addition to their practical aspects, which makes them powerful materials in green space design. Creating beautiful contrasts by using cover plants because of their high color diversity (ranging from gray to light green and grassy green, tan to purple and green pied compounds and gray, or yellow and white) and variety of tissues (leafy tissue from grass to rough textures) is not very difficult (Ghasemi Qahsareh and Kafi, 2010). These plants decrease apparent chaos in the design and therefore mental anguish in people by creating unity. They have the ability to connect non-related elements to each other and also soften the sharp edges and angles in green spaces. These plants are the best choice to display ups and downs of the ground and the eliminate monotony in green spaces. From practical aspects, cover plants are suitable options for cultivation in freeways and roadsides because of their ability in light absorption and reduction of the light reflections (Mackenaize, 2003). These plants have the ability to be cultivated in sloping areas and steep slopes, areas with full shade and permanent humid or dry conditions. Cover plants are also planted in areas where tree roots compete for food and water (Ghasemi Qahsareh and Kafi, 2010; Shooshtarian and Tehranifar, 2009; Bowker and Edinger, 1989). Maintenance requirement of these plants, such as the need for fertilizers and pruning, is low (Mackenaize, 2003). Despite lawns, some cover plants have adaptation capacity and survival in coastal regions in order to create green spaces in such regions (Shooshtarian and Tehranifar, 2011). These plants will not create the risks of lawn clippings and driving mowing machines around the buildings, trees, and shrubs in places such as patios, courtyards, narrow edges along fences, sidewalks, and downhill slopes with intense slopes. Therefore, using cover plants removes hard and dangerous practices which may take place in maintenance of lawns (Mackenaize, 2003). Shooshtarian and Tehranifar (2009) found that Frankenia, *Alyssum maritimum*, and *Vinca minor* are suitable plants to be replaced with lawn. *Vinca minor*, *Hedera helix*, *Carpobrotus* sp., and *Alyssum maritimum* can be used in steep areas and rock gardens.

3.4 Points to consider when using cover plants and mulches in landscapes

Mulches are not able to stabilize soil on steep areas. When they are decomposed, wooden materials release phenolic acid. Also, under small cultivation areas, such as in nurseries, acidification can be seen while this is less evident in field conditions. Living mulches compete on water and nutrient uptake with plants in green spaces (Chalker-Scott, 2007). In a study in Florida, 18 samples of 22 studied samples, which were processed from green and wood wastes, contained arsenic acid more than usual which caused chemical pollutions (Townsed *et al*., 2003). In another study, it was shown that rubber mulch is the most flammable mulch. Organic mulches with fine textures (dry needle-shaped leaves, straw, and bark pieces), organic mulches with coarse textures (wood chips, pieces of bark, cocoa hulls), mulches with high water levels (municipal waste composts and clipping of grasses), and pieces of bricks were located in the next places in terms of flammability (Steward *et al*., 2003). A notable point in using wood as mulch is survival of pathogens on it after the wood is converted to mulch. In most cases, pallets and other packaging materials infected with native and non-native pathogens. Because of using non-compost wood chips, which are produced from wood packaging materials, the risk of exotic pathogens is increased (Koshi and Jocobi, 2004). In addition, we should be careful about the presence of termites when wood-base mulches are used. When pine and cypress bark were used as mulches, 64% to 77% of termites survived (Duryea *et al*., 1999). In using cover plants in green space development, it should be noted that only a species or a few numbers of species should be used in order to prevent creating a busy landscape. Using large-leave cover plants on great scales and small-leave cover plants in small scales is better. Also, in combined cultivations, we should use plants that would coexist with each other and complement each other in terms of maintenance needs, color, texture, form, and size. Cover plants with different growing habits must not be used beside each other in green spaces (Mackenaize, 2003).

4. Conclusion

Since green spaces are inevitable parts of the city environments and contribute by environmental, recreational, aesthetic, and functional benefits to urban areas, their development and maintenance is one of the main goals and major issues in urban planning and management. However, limitations of arid and semi-arid cities in development and expansion of urban green spaces emphasizes the need for using the right landscaping materials. Appropriate mulches and cover plants have outstanding environmental features, such as erosion control, ability to deal with weeds, and moderating soil temperature and moisture and oxygen as well as outstanding visual and aesthetic characteristics by bringing a large variety of textures and colors to urban green spaces. They reduce evaporation from the soil surface or evapotranspiration from the soil and plants, maintain soil moisture for longer time in the soil, and save water, labor, and time in green space irrigations in arid regions.

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