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Effect of mulches on some characteristics of a drought tolerant flowering plant for urban landscaping

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Abstract

Mulches are relatively new landscape components and becoming recognized for their environmental and aesthetic outcomes on urban landscapes especially in arid environments. However, the effects of mulches on landscape plants have not been extensively discussed. This study examined the effects of organic and inorganic mulches on the performance of the widely used herbaceous drought tolerant flowering plant of *Zinnia elegans*. This study was designed as a randomized complete block design with three replications. Four widely commercially available and utilized mulches, including wood chips, pine needles, scoria (volcanic stone) and black polyethylene were used as the treatment mulches. The study contained plots with only bare soil as the control. The results showed that utilizing the selected mulches have positive effects on the plant growth, and increased the fresh and dry weight of shoots ($p<0.05$) compared to the control. In the *Zinnia,* the highest fresh and dry weights were recorded for the wood chip treatment. The mulches decreased the percentage of the weeds ($p<0.01$) in the beds compared to the bare soil. The highest water use efficiencies were recorded when polyethylene, wood chips (M=16 kg/m3) and pine needles were used as mulches, respectively. Mulches increased the flowering period up to 6 days and decreased the number of days to flowering up to 19 days with polyethylene mulch compared to the control treatment. Therefore, utilizing organic and inorganic mulches for improving landscape quality, performance and aesthetics especially in arid environments is recommended.

Keywords: Flowering plants; Mulch; Green space; Drought stress; Zinnia

1. Introduction

Mulches, as natural or synthetic substances cover the soil surface to protect and promote its quality in landscapes (Cregg and Schutzki, 2009, Safari and Kazemi, 2016). Bare soil exposed to heat and the wind, loses water through evaporation and using mulches increases the soils water retention, reduces evaporation and number of weeds (Plekhanova and Petrova, 2002) and moderate soil moisture and temperature (Skroch, 1992). These are valuable outputs especially in more fragile and low water landscapes such as arid environments. Mulches protect soils from the wind, water and traffic induced erosion in cities or wind induced erosions in deserts (Akbarnia, 2009) and can reduce root stress and poor plant health (Chalker-Scott, 2007, Safari and Kazemi, 2016). Most studies have focused on the effect of mulches on agricultural crops, for example, Rubeiz and Freiwat (1995) in tomato, López-Tolentino *et al*., (2016) in cucumber, and Zhang *et al*. (2015) in maize showed by using black plastic mulches early crop production can be enhanced and the yield can be increased. Berglund *et al*. (2006) showed establishment of strawberry is more rapid and effective using degradable plastic mulches. In agricultural crops, it appears the number of studies on layer mulches is more than those conducted on other types of mulches. However, there are at least research evidences on increase of yield in plantain using woodchips, sawdust and palm bunch refuse (Obiefuna, 1991); growth promoting effects using wood fiber mulch on lettuce (Gruda, 2008) and small reduction in

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total number of flowers in calla as an ornamental plant using sawdust mulch (Wright and Burgh, 2000). Further, in a study on the effects of mulch types on vegetable production in a green roof system, pine bark resulted in higher productivity than live sedum mulch (Whittinghill *et al*., 2016).

In urban landscaping, there are intentions to move toward low maintenance landscapes especially low water consuming landscapes (Rabbani Kheirkhah and Kazemi, 2015) either by changing the method or systems of landscaping (e.g. water sensitive landscaping (Kazemi *et al*., 2011, Kazemi, Hill, 2015, Kazemi and Mohoroko, 2017) or xeriscaping (Kazemi and Beecham, 2008) that one of its principles is mulching. Despite their high maintenance, ornamental flower beds provide beauty and color and therefore; it is hard to convince people to eliminate them from urban landscapes for the benefit of low maintenance urban landscaping (Bromley, 2015). Considering the significance of bedding plants in urban landscapes, strategies should be discussed to combine mulches with bedding flowers to achieve lower inputs including maintenance and water resources. Limited research has been conducted in this area, though the work by Pakdel (2010) and Iies and Dosmann (1999) can be discussed. Pakdel (2010) investigated the effect of four types of mulches including wood chips, municipal compost, sawdust and gravel on the growth of *Platanus orientalis*, *Rosa masquerade* and *Tagetes patula*. The generalized results of growth factors in all the plants were associated with sawdust, which illustrated the highest growth characteristics. In *Rosa masquerade*, the largest number of leaves, total fresh and dry weight, the fresh and dry weight of flowers, and fresh and dry weight of leaves; were recorded in sawdust, wood chips, compost, gravel and the controls, respectively. The study also demonstrated mulches increased the plant heights compared to the control treatment. In *Platanus orientalis*, the number of leaves, total fresh weight, fresh and dry weight of leaves and height increased compared to the control (Pakdel, 2010). In research conducted by Iies and Dosmann (1999), trees grown in river rock, crushed brick, pea gravel, and carmel rock, had larger stem circumference than those growing in shredded bark plots. The plants treated with crushed brick, pea gravel, and carmel rock treatments similarly resulted in greater leaf dry mass than the plans treated in shredded bark (Iies and Dosmann, 1999). Many bedding plants have different growing conditions, those with a tolerance to cool weather can include *Lobularia maritima*, *Antirrhinum* sp. and *Calendula* sp., while others like *Catharanthus roseus* and *Celosia* sp. tolerate and flourish in warmer weather conditions (Bromley, 2015). It has been demonstrated mulches have the ability to mitigate adverse weather conditions, which in turn could extend the survival and performance of a large variety of bedding plants. Likewise, mulches improve water retention capacity in the soil and weed control, which reduces maintenance requirements of bedding plants in ornamental landscapes. However, despite these assumptions, evidence on the performances of bedding plants in the presence of mulches continues to be limited and this research was conducted to fill in this important research gap.

Zinnia elegans is recognized as a commonly utilized drought tolerant bedding plant in ornamental landscaping in many places of the world. However, the performance of this plant species in conjunction with mulches as soil covers has fewer investigations. Therefore, in this study, the effect and evaluation of four mulch types on growth and morpho-physiological traits of *Zinnia elegans* was evaluated.

2. Materials and Methods

2.1. Site description, experimental design and plant material

To investigate the effect of different organic and inorganic mulches *on Zinnia elegans*, this field experiment was performed during spring and summer of 2015, at the experimental fields of the Department of Horticulture and Landscape in the Agricultural College of Ferdowsi University of Mashhad, Iran recognized as both an arid and semi-arid climate (59038′ E and 360 16′ N; elevation 989m a.s.l.; mean annual rainfall 255.2 mm). This study was designed as a randomized complete block design with three replications.

First, *Zinnia* seeds were sown in planting trays in a growing medium containing a mixture of soil and coco peat and were maintained under greenhouse conditions. The seedlings were then transferred to the main plots in April 2016. Texture of plots soil was loam. Some physicochemical properties of the used soil are listed in Table 1.

Table 1. Physicochemical properties of the used soil

	Texture	pH	EC(ds/m)	N (mg/kg)	P (mg/kg)	K (mg/kg)
Soil	loam	7.56	3.98	1498	56.6	409

The plots were covered with a 7 cm mulch layer during the experiment. Four widely used and commercially available mulches of wood chips, pine needles, scoria (volcanic stone) and black polyethylene layer were used as the treatment mulches. Bare soil was defined as the control treatment (Figure 1).

Fig. 1. Demonstration of the experimental design site

Where applicable, samples were collected from each mulch type and their physical properties were measured. Some physical properties of these mulches are listed in Table 2. These measurements were not applicable for black polyethylene mulch.

Table 2. Physical properties of the used mulches

	Apparent dry weight (gr)	Bulk density (gr/cm^3)	Length / diameter of particles (mm)
Wood chips	27.71	0.92	14
Pine needles	9.61	0.96	8.50
Scoria	131.25	1.64	3.50

Irrigation was conducted according to the field capacity of the soil every three days. Available water for plants was calculated using the following formula:

$$AW = (FC - PWP) \times R_d \quad (1)$$

In formula 1 AW is indicative for available water, FC is indicative for field capacity, PWP is indicative for permanent wilting point and R_d is indicative for effective root depth. In this experiment, effective root depth was 15 cm. Determination of field capacity and permanent wilting point was conducted based on the method suggested by Salter and Haworth (1961).

2.2. Measured factors

Morphological and physiological factors of the plant species and environmental factors including the percentage of weeds were measured at the end of the experiment. Plant heights were measured using a metric ruler, and the flower diameters and stem diameters were measured with a digital caliper. Shoot and root fresh weights were measured using a scale with an accuracy of 0.001 gr. The roots and shoots were dried in an oven with temperature no more than 65 °C according to Kazemi *et al*. (2011) until a constant weight was achieved. Number of the plant nodes and leaves were counted and the percentage of plant coverage measured in plots of 1m 3 1m. The flowering period was recorded according to Salehi sardoei *et al*. (2014). The Chlorophyll index was measured with a SPAD meter (SPAD 502, Konica-Minohta- Tokyo) to quantify chlorophyll content or “greenness” of the plants. The amount of chlorophyll a and chlorophyll b were measured at the end of the experiment (Dere *et al*., 1998). Relative Water Content (RWC) (Hernandez-Sebastia *et al*., 1999), Leaf Relative Water Loss (RWL) (Shaban *et al*., 2012) and Electrical Leakage (EL) (Marcum, 1998) were measured at the end of the trial. The overall health of the plants was ranked using a 1-9 scale ranking approach (1: the lowest quality, 9: the best quality). The soil temperature was measured monthly by a thermometer (TH 310) from 5 cm depth of the soil. Water use efficiency was measured based on the following formula (formula 2) (Ahrar *et al*., 2009):

WUE (Kg/m^3)=(The amount of plant dry matter produced) ⁄ total water available for plant (2)

The soil moisture was also recorded from 5 Cm and 15 Cm depths of the soil using a moisture meter (EXTECH MO750, USA) each month at 10.00 am.

2.3. Statistical Analyses

The empirical data were analyzed using Analysis variance (ANOVA) test and software package of JMP V.8. Comparisons of the means were conducted using Least Significant Difference (LSD) tests. The significance of between-treatment means was tested at 0.01 and 0.05 levels of probability. The bar graphs were drawn utilizing a Microsoft Excel software package.

3. Results

The results of the analysis of variance showed that some morphological traits were also significant at 1% or 5% probability levels when the different types of mulches were used on top of the soil around *Zinnia elegans* (Table 3).

Some physiological and phenological traits were also significant at 1% or 5% probability levels when the different types of mulches were used on top of the soil around Zinnia elegans (Table 4).

Additionally, the results showed that the mulches had a significant effect on plants height. Among all the treated plants, those which were planted through polyethylene mulch had the highest height, while those treated with scoria possessed the shortest heights (Table 5).

The stem diameter was also significantly affected using the different mulches, the plants associated with polyethylene mulch had the largest stem diameters and those associated with scoria had the smallest stem diameter. Among the plant groups treated by the mulches, those treated by polyethylene mulch had the largest fresh weight of shoots and those not surrounded with any type of mulch had the smallest weight in their fresh shoots.

The fresh weight of roots was affected similarly by most of the mulches, though, wood chip mulch presented the largest positive effect on this factor (Table 5). Again, dry weight of shoots in *Zinnia* was significantly affected by all the mulches, and there were fewer differences in this aspect among the different mulches. However, an absence of mulch had a significant negative effect on the dry shoot weight of Zinnia, presenting the lowest dry weight of the shoots. For the dry weight of roots, the plants covered with wood chips had the highest dry weight while the plants covered with scoria and those not covered with any mulch showed the least root dry weight. The overall health of the plants was statistically positively affected when mulches were utilized when compared with the plants not surrounded with any mulch. The largest number of nodes was recorded on the plants grown in soil covered with polyethylene layer mulch. The use of the selected mulches except scoria had no significant effect on the *Zinnia* coverage; however, scoria had a negative effect on percentage coverage of *Zinnia*. Wood chips and polyethylene mulch increased the number of leaves per plant compared to using or not using other mulches. Similarly, the use of polyethylene and scoria mulches increased the number of lateral branches compared to using the other mulches and also those in the control treatment (Table 5).

The largest amount of chlorophyll a was recorded when pine needles and polyethylene were used as mulches. Using polyethylene and wood chips significantly increased flowering period in Zinnia (Table 5).

Based on Figure 2.A utilizing all type of mulches increased the water use efficiency in Zinnia compared to the bare soil (control). Although the differences between using different types of mulches on water use efficiency of Zinnia was observationally large, it was not statistically significant.

Using mulches on the soil surface reduced percentage coverage of weeds (%). Polyethylene mulch completely prevented growing the weeds from the plant beds. Also other types of mulches significantly reduced the weed coverage in this experiment compared to the control bare soil (Fig. 2. B).

In general, the use of polyethylene and wood chip reduced number of the days to flowering compared to using other types of mulches. In the control treatment, reproductive phase of the plants increased (Fig. 2. D). However, using polyethylene and wood chip mulches increased overall period of flowering (Fig. 2. C).

Table 3. Analysis of variance of some morphological traits in *Zinnia elegans*

ANOVA	d_f	Height	Stem diameter	Flower diameter	Fresh weight of shoot	Fresh weight of root	Dry weight of shoot	Dry weight of root	Overall health	Number of nodes	Plant coverage	Number of leaves	Number of lateral branches
Replication	2	58.867^{ns}	0.026 ^{ns}	34.30^{ns}	950.02 ^{ns}	81.17 ^{ns}	68.639^{ns}	4.896 ^{ns}	0.800^{ns}	2.066*	1501792^{ns}	11938.40^{ns}	0.466 ^{ns}
Mulch	4	2082.7**	0.144 **	77.20*	33342.19**	229.03 *	5034.53*	20.522**	5.433**	4.900*	6716093*	16694.23*	7.100 **
Error	8	57.12	0.006	17.26	3319.9	44.827	857.55	2.150	0.383	1.150	1228911	3290.2	0.300

** Significant at 1% level of probability, * Significant at 5% level of probability, ns: Non-significant

Table 4. Analysis of variance of some physiological and phonological traits in *Zinnia elegans*

ANOVA	d_f	Chlorophyll a	Chlorophyll b	SPAD	RWC	RWL	EL	Flowering period	Number of the days to flowering	Water use efficiency	Weed
Replication	2	0.028*	0.0006 ^{ns}	3.400 ^{ns}	174.747 ^{ns}	62.799^{ns}	365.606^{ns}	22.200^{ns}	21.800 ^{ns}	0/46 ^{ns}	65.00^{ns}
Mulch	4	0.044**	0.005 ^{ns}	20.630 ^{ns}	156.591 ^{ns}	145.813 ^{ns}	147.454^{ns}	115.433 *	242.23**	52.59*	2414.16**
Error	8	0.004	0.002	34.523	271.822	191.794	226.090	19.033	34.38	8.80	87.92

** Significant at 1% level of probability, * Significant at 5% level of probability, ns: Non-significant

Table 5. The effect of mulches on some morphological and physiological characteristics of *Zinnia elegans*

Mulch	Height (cm)	Stem diameter (cm)	Flower diameter (mm)	Fresh weight of shoot (gr)	Fresh weight of root (gr)	Dry weight of shoot (gr)	Dry weight of root (gr)	Overall health	Number of nodes	Plant coverage (cm^2)	Number of leaves	Number of lateral branches	Chlorophyll a (µg/ml)
Polyethylene	146.00a	1.53a	98.81a	473.133a	28.03b	155.817 a	8.01bc	9.00a	9.66a	6860.66a	276.66ab	9.66a	0.77ab
Wood chips	125.00b	1.10b	88.59b	363.490b	42.63a	152.38 a	12.36a	8.66a	7.66abc	5000.00a	375.00a	6.33b	0.55c
Pine needles	113.00bc	1.16b	87.68b	365.716ab	31.79ab	112.263 a	9.98ab	8.33ab	7.33bc	5889.66a	264.33b	6.66b	0.86a
Scoria	74.33d	0.93c	85.76b	324.846b	19.45b	101.520ab	6.33c	7.33b	8.66ab	2814.00b	231.33b	8.66a	0.67bc
Bare soil (control)	106.00c	1.16b	89.76b	180.933c	24.53b	56.160 b	6.19c	5.66c	6.33c	5088.33a	170.66b	6.33b	0.65bc

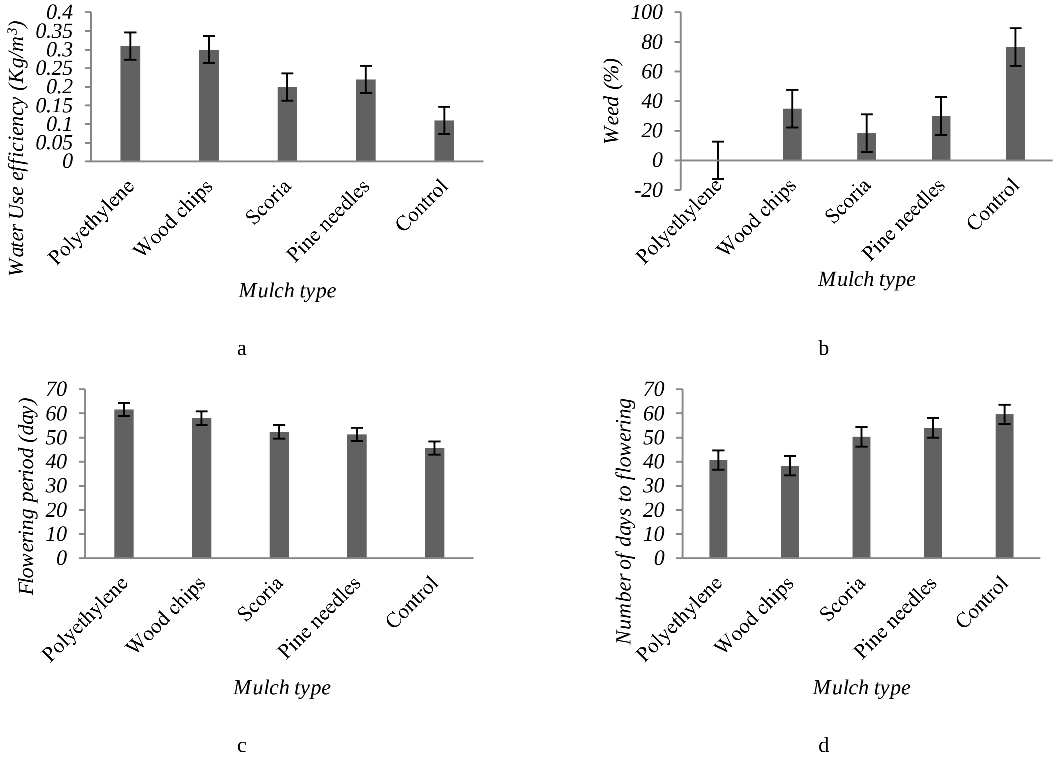

Fig. 2. The effect of mulches on; water use efficiency (a) , weed coverage (%) (b), flowering period (c) and number of the days to flowering (d)

The graphs (Fig. 3) on the soil moistures did not present a distinctive pattern when using the selected types of mulch. However, at 15 cm depth of the soil, it was obvious that applying mulches increased the soil moisture compared to the soil moisture of the bare soil control, especially in warm months during the period of the experiment (Fig. 3).

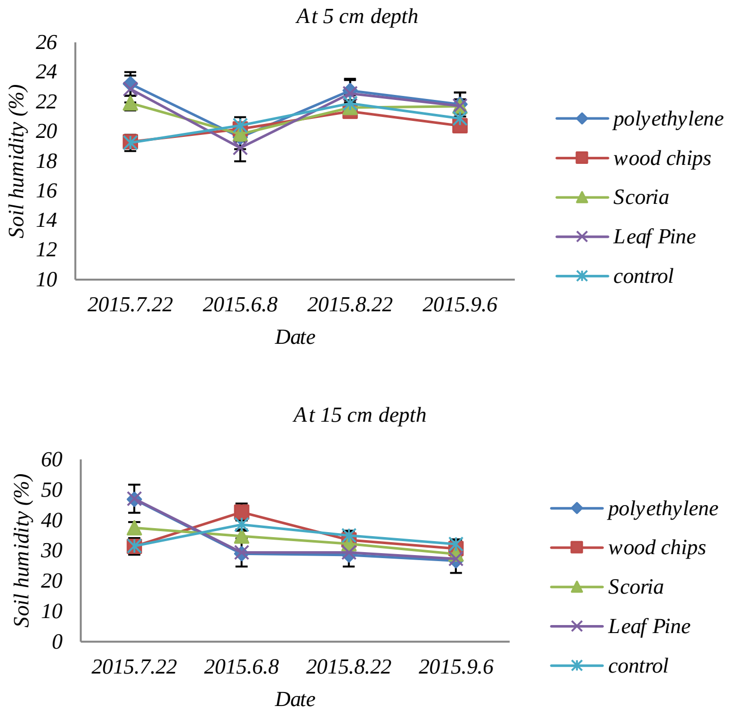

Fig. 3. Effects of mulch types on soil humidity at different depths

According to Figure 4, scoria, pine needles and wood chips reduced the soil temperature compared to the bare soil in warm months during the experimental period. However, polyethylene layer increased the soil temperature more than bare soil.

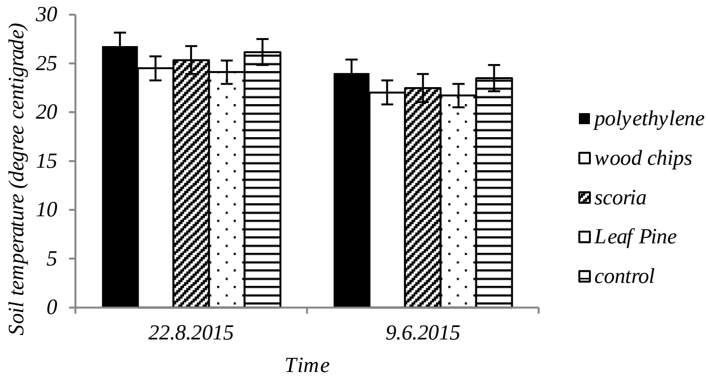

Fig. 4. Effects of mulch types on soil temperature at two different times of sampling

4. Discussion

Mulches are essential components to improve the sustainability of landscape systems and have many positive effects on soil and plants (Cregg and Schutzki, 2009). In this investigation, mulches provided improved conditions for generating plant biomasses and enhancing general health of the plants by increasing the fresh and dry weight of the roots and shoots compared to the control non-mulched treatments. The mulches improved the plants growth by increasing number of nodes, leaves and lateral branches. However, organic mulches can increase, decrease or even have no effect upon nutrient levels depending on mulch types, soil chemistry and particular nutrients of interest. Mulches with relatively high nitrogen content often result in higher yields (Bowker and Edinger, 1989). Mulches can enhance root establishment and increased plant performance because improved water retention created by mulches encourages roots to extend and establish beyond the trunk compared to those in bare soil. Plants with stronger root systems consequently become established more quickly. Root development under organic mulches is therefore greater when compared to bare soil (Koshki and Jocobi, 2004).

Organic and non-organic mulching provides an important method for non-chemical intervention to control weeds (Takasi, 2006). In this study, the use of mulches on the soil surface reduced the percentage coverage of weeds (Figure 2B). As discussed by Chalker-Scott (2007), weeds and bare soil increased evaporation by 25% on summer days. Reducing weeds lead to increased moisture content in the soil, and consequently reduction in irrigation levels. Reducing weed competition decreased the competition for resources with the cultivated plant, allowing for greater productivity (Chalker-Scott, 2007). This finding was confirmed by the results of current research, the beds covered with mulches were associated with plants with greater growth factors. In this study, polyethylene plastic mulch prevented weed growth completely, while the other mulches reduced weeds by a significant percentage (Figure 2B). The use of polyethylene as a mulch type has been widely used in agriculture to suppress weeds perhaps because of ease to apply and cost (Ramakrishna *et al*., 2006; Kashi *et al*., 2003, Plekhanova and Petrova, 2002) and to retain soil moisture (Kashi *et al*., 2003). Some of the mulches absorb wavelengths suitable for germination and growth of weeds; thereby mulches can reduce the percentage of weeds (Chalker-Scott, 2007). The heating capability of the black mulch is greater because of the degree of physical contact between the mulch and the soil surface increases. A black mulch, stretched tightly on the soil surface absorbs shortwave radiation, which then heats up and transfers energy to the soil more efficiently, mostly by conduction, than a loose-contact film (Bonachela *et al*., 2012). In another study, the soil temperature increased by about 5 °C when polyethylene was used as the mulch type (Ghosh *et al*., 2006). Also, depending on the amount of lights absorbed or reflected by plastic mulches, they can increase or decrease temperatures of the soil (Chalker-Scott, 2007). The soil temperature can influence the distribution of flora and fauna, biological activities and water movement in the soil (Ghaemi nia *et al*., 2011). Mulches are useful in moderate temperatures and help protect plants from extreme temperatures (Nasrollazadeh asl and Dastparchin, 2015). In this study, mulches which kept the soil temperature relatively moderate around the root zone provided the changes to some of the plant growth traits.

Any factor that can increase plant performances especially plant biomasses and reduce evapotranspiration; increases water use efficiency (Heydari and Deljoo, 2012). One of the practical solutions to maintain soil moisture for longer period and increase water use efficiency in plants is through applying mulches on the soil surface (Ramakrishna *et al*., 2006). The term water efficient agriculture using mulches especially plastic films has brought significant advantages to crop production especially in arid region (Yang *et al*., 2015). In this experiment, mulches enhanced water use efficiency in *Zinnia elegans* when a comparison was made with the bare soil as the control treatment. Our findings are consistent with the results of a study by Ramakrishna *et al.* (2006) on Broccoli. The water use efficiency in Broccoli was increased from 1.4 to 4.8 Kg/cm^3 when a polyethylene layer mulch was used at planting (Ramakrishna *et al*., 2006). Therefore, mulching reduced irrigation requirements by decreasing surface evaporation and runoff and also protected the soil from compaction by rain and foot traffic (Bowker and Edinger, 1989). Similarly, mulched plants are shown to have larger root systems than non-mulched plants, improving the plants capacity to uptake water (Skroch *et al*., 1992).

Polyethylene mulch also affects plant height, growth and flowering (Ramakrishna *et al*., 2006), soil porosity (Kashi *et al*., 2003) and total yield of the agricultural products (Kashi *et al*., 2003). For example, enhancing early crop production and increasing the yield which is related to early flowering using black plastic mulches have been confirmed in many horticultural crops including tomatoes (Rubeiz and Freiwat, 1995), cucumbers (López-Tolentino *et al*., 2016) and maize (Zhang *et al*., 2015). Not any research was found yet to show using plastic mulches can enhance early flowering of ornamental plants in urban landscapes. However, similar to the results on early crop production which is related to early flowering, this study confirmed that utilizing mulches decreased time to flowering, when they did flower the flowering period increased. This is a valuable landscape quality and novel knowledge that many landscape designers, managers and architects can consider and which can be achieved by polyethylene mulching of planting beds. Despite this finding, there are environmental concerns on using polyethylene mulches, for example their degradation as agro-environmental pollutions (Yang, 2015) and their negative effect on soil carbon storage and controlling greenhouse gas emissions (Zhang *et al*., 2015). Such disadvantages can be overcome using more environmentally friendly materials such as degradable films (Berglund *et al*., 2006, López-Tolentino *et al.*, 2016) and recycled paper mulches (Anderson *et al*., 1995). Using such biodegradable mulches appears to bring advantages of normal plastic mulches to agricultural crops while have no negative ecological impacts on the soil (Fernando *et al*., 2002, López-Tolentino *et al*., 2016). However, landscape performances of these mulches combined with plants needs to be investigated more in future research before there are widely used in urban landscaping.

5. Conclusion

The current study confirmed the finding of the previous publications that mulches can enhance the quality of planting and landscaping. It also provided knowledge in that some mulches can promote early flowering and can increase flowering period in *Zinnia elegans* which is a positive feature in urban planting designs. However, the degree in which the mulches affect physiological and morphological factors in different plants need to be further investigated to understand how to combine plants with different types of mulches in urban planting designs.

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