DESERT

Desert
Online at http://desert.ut.ac.ir

Desert 25-2 (2020) 155-164

The effect of organic and inorganic mulches on growth and morphophysiological characteristics of *Gaillardia* sp.

F. Kazemi[*a], M. Jozay[a]

[a] *Department of Horticulture and Landscape, Ferdowsi University of Mashhad, Mashhad, Iran*

Received: 9 October 2019; Received in revised form: 13 February 2020; Accepted: 18 February 2020

Abstract

Considering a large number of cities located in arid and semi-arid climatic regions of the world with limited water resources, reducing water consumption and maintenance costs is an important research and implementation priority in urban landscaping. In other words, reducing the high costs of irrigation, increasing water use efficiency and reducing weed competition are important factors in achieving sustainable green spaces in arid and semiarid regions. Application of mulches is one of the suggested strategies for maintaining bed moisture and weed control. In this research, the effects of organic and inorganic mulches on the performance of the flowering plant of Blanket flower (*Gaillardia* sp.) were investigated in the arid climate city of Mashhad located in the northeast of Iran. The experiment was conducted as a randomized complete block design with three replications. The four mulch treatments included wood chips, scoria, pine leaves, polyethylene as a layer mulch, and no mulch as the control. The polyethylene mulch inhibited the weed growth up to 100%, and other mulch types also significantly reduced the percentage of the weed coverage ($p \leq 0.01$). Application of pine leaves delayed the flowering for seven days while polyethylene caused an early flowering to six days compared to the control. Using different mulch types in water shortage conditions of urban landscapes in arid and semi-arid regions is recommended.

Keywords: Mulch; *Gaillardia* sp.; Weed; Water saving; Flowering

1. Introduction

Water scarcity is an environmental constraint for plant growth and development especially in arid and semi-arid urban environments (Farooq *et al.*, 2009). In recent years, with the rapid development of agriculture and industry, the scarcity of water, especially in arid and semi-arid climate regions of the world, is increasing. In such regions, the limited water resources especially groundwaters are almost at the risk of over-harvesting. All these points double the need to find solutions to conserve water for all usages, including for green spaces which are considered as luxury consumers of the municipal water. To increase the efficiency of water consumption in urban landscaping, the term xeriscaping has been proposed. This term has several principles including, but not limited to, soil mulching, selection of native and adapted plants to the area, application of new methods of irrigation and soil enhancement (Zhao *et al.*, 2014). Mulches are divided into organic and inorganic types and have a high diversity of wood products including wood chips of different types of trees to recycled pallets, pine straw, composted animal manure, some crops, and other organic mulches. Brick fragments, rubber crumbs, decomposed granite, all kinds of rocks and gravel, polyethylene and pebbles are also inorganic mulch types (Singer and Martin, 2008).

The benefits of mulching are maintaining moisture and temperature equilibrium in the root zone, reducing the evaporation from the soil, preventing soil erosion, improving soil properties and structure, and suppressing weeds and preventing seed germination. Mulches also add to the aesthetic features of the landscape and affect the soil pH (Singer and Martin,

[*] Corresponding author. Tel.: +98 51 38805756
Fax: +98 51 38805756
E-mail address: fatemeh.kazemi@um.ac.ir

2008). Accumulation of the organic acids produced by the decomposition of abiotic mulches after washing into the soil reduces the soil pH (Iies and Dosmann, 1999). Lead and cadmium, which are most commonly contaminations in urban areas can be removed from the soil by eucalyptus, pine, populous, and cedar leaves (Salim and El-Halawa, 2002). Mulches cause the root of the plants to settle more rapidly in the soil which results in faster growth of the plants (Kazemi and Safari, 2018). Whitingel *et al*. (2016) investigated the effects of three types of mulches (pine bark, living sedums, and no mulch), and three types of fertigation regimes on the cultivation of some vegetables under green roof conditions. Mulches differed in their effects on vegetable yield, and pine bark had a better performance on vegetables than sedum as a living mulch. Sedum mitigated the temperature of the substrate and improved the health of the vegetables during drought conditions. In contrast, during the periods with no water restrictions, sedum competed with the herbaceous plants and reduced their growth. Being informed about such a mechanism may be useful for efficient management of the green roof systems. Despite the above-mentioned research work, the pieces of research to provide evidence on the effect of mulch types on the landscape plants especially the flowering plants in the landscape are limited. For example, in research on *Platanus orientalis*, Pakdel *et al.* (2011b) found that all types of the used mulches including sawdust, wood chips, compost, and sand increased the plant growth parameters compared to the control non-mulched treatments although there were no differences between the mulch types in terms of such effects. It appeared that sawdust could improve the plant growth better than other mulch types by preserving the soil moisture and mitigating the drought stress. In another research on two cultivars of parsley used in urban green space of the semi-arid city of Mashhad, Pakdel *et al.* (2011a) investigated the effect of four types of mulches with three different thicknesses on soil temperature, humidity, and some plant growth traits. The results showed that sawdust (with 12 cm thickness) had the largest mean soil moisture (23.62%), and the lowest mean soil temperature (25.01°C) during the growing season. In both cultivars, increasing the mulch thickness was associated with an increase in all the growing traits of the plants.

The flowering species provide color, texture, and forms into the urban landscapes. Therefore, finding the most water-conserving species to be mixed with mulches for sustainable landscaping is a challenge (Kazemi and Safari, 2018). *Gaillardia* sp. as a drought-resistant medicinal and ornamental species is a candidate plant for xeric landscaping. *Gaillardia* sp. is one of the most beautiful herbaceous plants with beautiful flowers flourishing from early summer to mid-autumn. Salve *et al.* (2019) reported some analgesic and disinfectant effects of this plant for wounds. The dried part of *Gaillardia* sp. is also useful for colds, its fumigation can relieve headaches, and its extract is also useful in the treatment of liver, lung, spleen and bladder diseases (Salve *et al.*, 2019).

Flowers are one of the important features affecting the aesthetic of the landscapes and their long-lasting character especially in less aesthetically perceived landscapes such as xeriscapes can enhance the sense of beauty in these landscapes. Therefore, to address this research gap, the current research will focus on some growth and morphophysiological characteristics including the flowering period of the important flowering plant of *Gaillardia* sp. under treatment with some organic and inorganic mulches.

2. Materials and Methods

2.1. Site description, experimental design and plant material

The study was conducted at the Research Gardens of Ferdowsi University of Mashhad, Mashhad in the northeast of Iran. Located in an arid and semi-arid region, Mashhad has an average annual rainfall of 255.5 mm. The minimum and maximum annual temperatures are -4$^{\circ C}$ and -22$^{\circ C}$, respectively (National Centers for Climatology, 2019).

The experiment included different plant species but only the results of *Gaillardia* sp. has been reported in this paper.

Gaillardia sp. as one of the important medicinal-ornamental plants which are common in urban landscaping of Iran was selected as the species to work in this experiment. This plant is practically drought tolerant and well adapted to climatic conditions of the city of Mashhad.

The seeds were planted in the transplant trays containing a mixture of coir fiber and perlite and were kept in the greenhouse conditions and then transferred to the experimental field. The soil texture was loam and other physicochemical properties of the field soil have been reported in Table 1.

Table 1. Physicochemical properties of the soil of the experimental field

	Texture	pH	EC(ds/m)	N (mg/kg)	P (mg/kg)	K (mg/kg)
Soil	Loam	7.56	3.98	1498.00	56.60	409.00

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

Table 2. Physical properties of the used mulches

	Apparent dry weight (gr)	Bulk density (gr/cm3)	Length / diameter of particles (mm)
Wood chips	27.71	0.92	14.00
Pine needles	9.61	0.96	8.50
Scoria	131.25	1.64	3.50

The experiment was conducted as a randomized complete block design with three replications. The four treatments included wood chips mulch, scoria, polyethylene, pine leaves and no mulch as the control treatment (Fig. 1).

Fig. 1. Demonstration of the experimental design site,
Note: The experiment included different plant species but only the results of *Gaillardia* sp. Have been reported in this paper

Soil moistures were recorded from the depths of 5 cm and 15 cm of the soil using an EXTECH MO750, made in the USA at 10 am each month. The soil temperatures were also measured between 12 to 2 noon by a soil thermometer (TH 310) from the depth of 5 cm every month. The leaf relative water content (RWC) was measured using the following formula (Hossain *et al*., 2010).

$$RWC = \frac{\mathrm{Fw-Dw}}{\mathrm{Tw-Dw}} \times 100 \qquad (1)$$

where Fw is fresh weight, Dw is dry weight and Tw is leaf dry weight. The weight measurements were conducted with 0.001 gram accuracy. Also, the root and shoot dry weight were measured by drying the specimens at 65 ^{o}C as described by the previous researchers (Kazemi *et al*., 2011).

2.2. Measured factors

The flowering time was calculated based on the number of days from planting to flowering. Flowering duration or period was defined as the start time of the flowering up to the time when the plant had 50% flourished flowers. This definition was based on Salehi Sardoui *et al*. (2014). Plant health was rated using a rating scale of 1 to 9 (1: the lowest quality, 9: the best quality). The content of chlorophyll a and chlorophyll b was determined according to Dere *et al*. (1998). Chlorophyll index was measured using a SPAD 502, Konica- Minolta-Tokyo. Irrigation was conducted every three days. The water requirement for the plants was calculated using the following formula:

$$AW = (FC - PWP) \qquad (2)$$

where AW is the available water of the plants, FC is the Field Capacity and PWP is the Permanent Wilting Point. Grain capacity and wilting point of the substrates were measured by the Salter and Havers's method (Salter and Haworth, 1961). Leaf Relative Water Loss (RWL) (Shaban *et al*., 2012) and Leaf Electrolyte Leakage (EL) (Marcum, 1998) were measured at the end of the experiment. Water Use Efficiency was also measured by AHAR method (Ahrar *et al*., 2009) and according to the following formula:

Water Use Efficiency (kg/m3) = amount of the produced plant biomass in a period / total water used by the plants at the same period

2.3. Statistical Analyses

Analyses of Variance were conducted on the data using the JMP8 software package for statistical analysis. Mean comparisons of the traits were performed using the Least Significant Difference (LSD) test at 1% and 5% probability levels. The graphs were drawn in an Excel software package.

3. Results

The results of the analysis of variance showed that some morphological and physiological characteristics in the studied plant were significant at 1% or 5% probability levels when different types of mulches were used on top of the cultivated soil with Blanket flower (Table 3).

Table 3. Analysis of variance of some physiological and phonological traits in *Gaillardia* sp.

s.o.v	Df	Number of the days to flowering	RWC	(SPAD)	Chlorophyll a	Chlorophyll b	Water use efficiency	Flowering period
Replication	2	^{ns} 1.86	98.35 ^{ns}	43.85 ^{ns}	0.001^{ns}	0.010^{ns}	0.00000 ^{ns}	^{ns} 2.86
Mulch	4	229.73**	146.24^{ns}	590.04 **	0.215**	* 0.027	0.00034**	80.90**
Error	8	5.03	182.44	45.57	0.012	0.007	0.00002	1.95

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

Table 4. Analysis of variance of some morphological traits in *Gaillardia* sp.

s.o.v	D_f	Height	Flower diameter	Stem diameter	Fresh weight of shoot	Fresh weight of root	Dry weight of shoot	Dry weight of root	Overall health	Weed
Replication	2	29.80^{ns}	36.92^{ns}	0.0010*	1296.46^{ns}	12.47^{ns}	0.14^{ns}	0.370^{ns}	0.06^{ns}	22.20^{ns}
Mulch	4	85.18**	30.46^{ns}	0.0009*	3346.58**	144.05**	85.94**	36.758**	3.43*	75.43**
Error	8	7.38	43.64	0.0002	465.70	10.15	5.17	0.980	0.73	6.28

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

The effects of mulch types on the percentage of weed coverage were significant at 1% probability level. Mean comparisons showed that the plants in the polyethylene mulch had the lowest percentage of weed coverage than the control treatment, indicating that the mulch had the best ability to control the growth of the weeds. Inorganic scoria wood chips and pine leaves were all effective in controlling the weed growth (Table 5).

Table 5. Comparison of the means of some measured traits in *Gaillardia* sp.

Mulch	Weed (%)	Flowering period	(SPAD)	Chlorophyl (µg/ml) l b	Chlorophyl l a (µg/ml)	Dry weight (gr) of root	Fresh weight of (gr) root	Dry weight of shoot (gr)	Fresh weight of shoot (gr)	Number of the days to flowering
Wood chips	8.66^{b}	59.33^{a}	51.870^{b}	0.48^{a}	1.08^{a}	2.78^{b}	6.10^{b}	21.21^{b}	80.70^{bc}	46.33^{b}
Pine needles	5.33^{b}	55.66^{b}	56.036^{b}	0.33^{ab}	0.54^{b}	9.85a	22.08^{a}	25.40^{ab}	135.41^{a}	53.00^{a}
Scoria	8.33^{b}	48.33^{c}	55.500^{b}	0.48^{a}	0.89^{a}	1.86^{b}	8.66^{b}	16.83^{c}	69.04b^{c}	46.00^{b}
Polyethylen	0.00^{c}	49.66^{c}	84.760^{a}	0.28^{b}	0.53^{b}	2.48^{b}	3.69^{b}	28.32^{a}	104.86^{ab}	40.66^{c}
control	13.66^{a}	47.33^{c}	51.400^{b}	0.31^{b}	0.48^{b}	1.36^{b}	5.97^{b}	15.93^{c}	49.03^{c}	46.66^{b}

The mulches had a significant effect on flowering duration (period) ($p\leq0.01$). The longest flowering period in *Gaillardia* sp. was related to the organic mulch of wood chips. The plants treated with pine leaves as the soil mulch was ranked as the second on the flowering period. However, the flowering period in the polyethylene and scoria as the inorganic mulches did not show a significant difference compared to the plants treated with no mulch as the control treatments and all the three treatments showed the shortest period of flowering in the studied plant (Table 5).

The number of days to flowering showed a significant difference when treatments with mulches occurred. The polyethylene mulch reduced the number of days to flowering compared to the other mulch types and also the control treatment. The start of the flowering in the plants treated with pine leaf mulch occurred later than that in the control (Table 5).

Chlorophyll a was significant at 1% probability level and chlorophyll b at 5% probability level under treatment of the plants with mulch types. A comparison of the means showed that the organic mulch of wood chips and inorganic mulches produced the best vegetation in *Gaillardia* sp. (Table 5).

Mulches had a significant effect on the fresh and dry weights of the shoots ($p \leq 0.01$). The highest fresh and dry weights of the aerial parts of the plants were related to the plants treated with the polyethylene and the pine leaf mulches and the lowest numbers of this factor were related with the plants treated with the scoria as the mulch type or those not treated with a mulch type (the control plants) (Table 5).

The fresh and dry weights of the plants under mulch treatments showed significant differences at 1% probability level. The plants had the highest root fresh and dry weight in the pine leaf mulch treatment, whereas these factors in the plants treated with other mulch types were not statistically different compared with those in the control treatment (Table 5).

Regarding the overall health of the plants, mulch treated plants showed a significant difference at the 5% probability level. The organic mulch of wood chips provided the best overall health in the plants, while the plants in the pine leaves and inorganic mulch of scoria also showed a better health performance than the plants in the control (Fig. 2b).

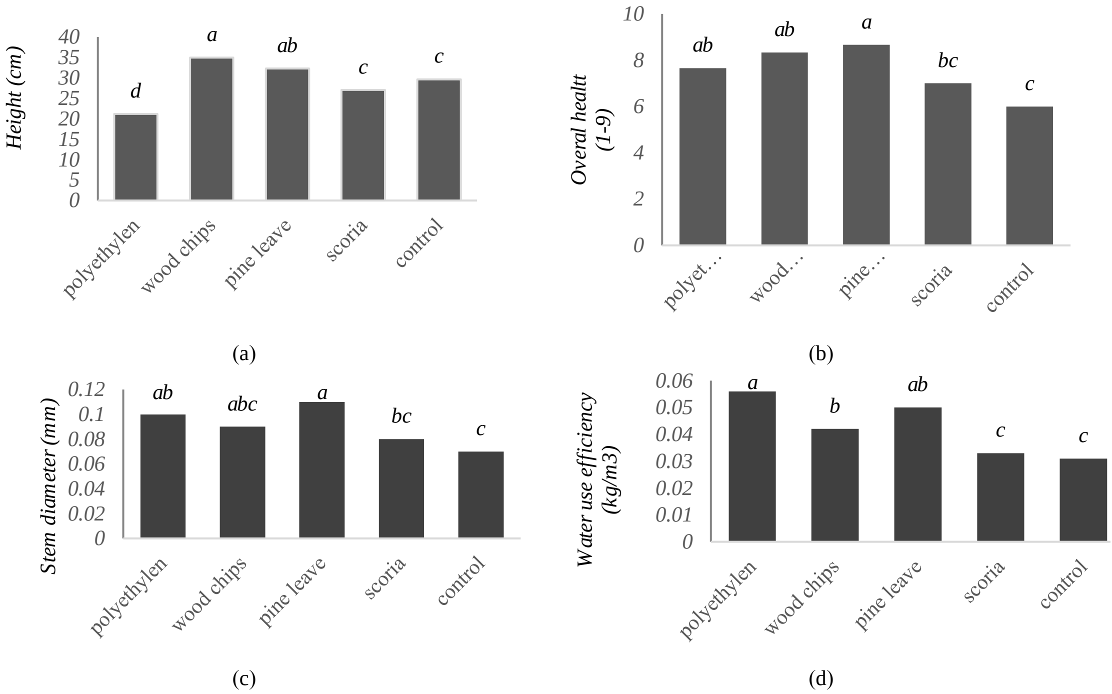

Fig. 2. The effect of mulches on; a. height, b. overall health, c. stem diameter, d. water use efficiency

Plant heights were significantly different under the treatments with mulches ($p \leq 0.01$). The plants treated with the wood chips mulch were associated with the highest plant height; while the plants under the treatment with polyethylene mulch had even less height than the plants in the control treatment (Fig. 2a).

According to the analysis of variance, the plants treated with the mulches had a significant difference in water use efficiency at 1% probability level. Polyethylene mulch made the most efficient use of water in the plants. The pine leaf mulch also increased water use efficiency in the plants compared to the control plants, but the inorganic mulch of scoria was not effective in increasing the water use efficiency (Fig. 2d).

The effect of different mulches on plant stem diameter showed a significant difference at the 5% probability level. The pine leaf mulch was associated with the highest stem diameter in the plants. After this mulch, the polyethylene and wood chips were associated with the plants with larger stem diameters than the control-treated plants (Fig. 2c).

As shown in Fig. 3, at 5 cm depth of the soil, all the mulch types maintained an increased soil moisture content and the highest moisture content was in the soils associated with the inorganic mulch of scoria. Polyethylene mulch seems to maintain less moisture in the soil compared to the other mulch types. However, mulched soils, disregarding of its type, always assisted in maintaining the soil moisture compared to the non-mulched soils.

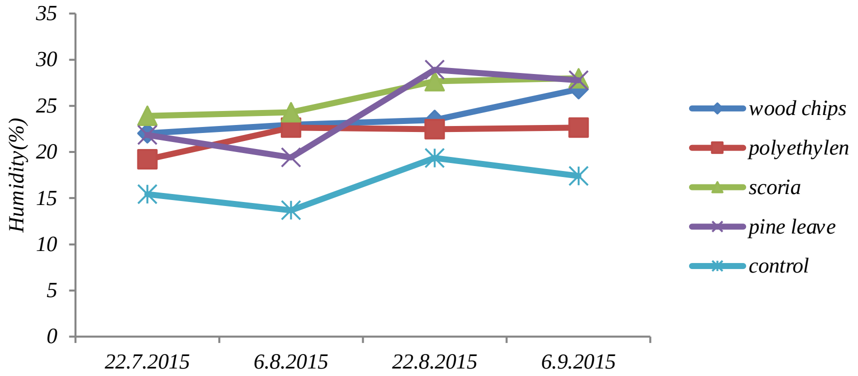

Fig. 3. Effects of mulch types on soil humidity at 5 cm soil depth

The humidity under the two mulch types of wood chips and the scoria were the same at 15 cm depth of the soil. These mulch types had better moisture retention capacity and maintained about 50% moisture content over time. Although the soil under the polyethylene and pine leaf mulches also maintained higher moisture than the soil without mulch treatments (controls), the moisture fluctuations under this mulch type were higher than those under the two mentioned mulches (Fig.4).

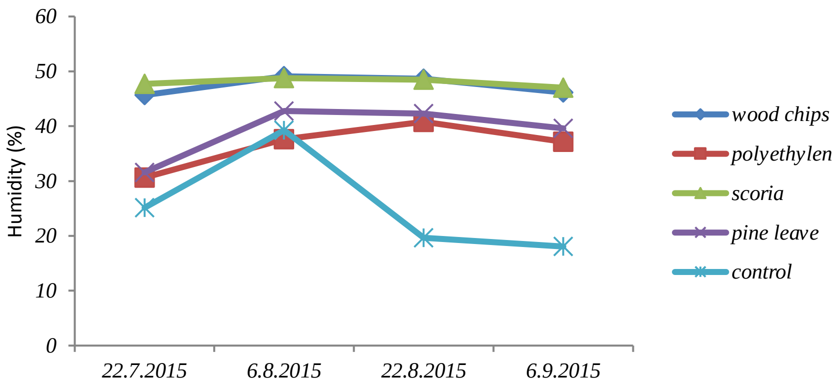

Fig. 4. Effects of mulch types on humidity at a soil depth of 15 cm

As shown in Fig. 5, all the mulch types were able to prevent soil warming in hot months compared to the non-mulched treated soils (controls). However, the soil mitigation ability of polyethylene was not as high as that in the other mulch types which may be due to the black color of this mulch type.

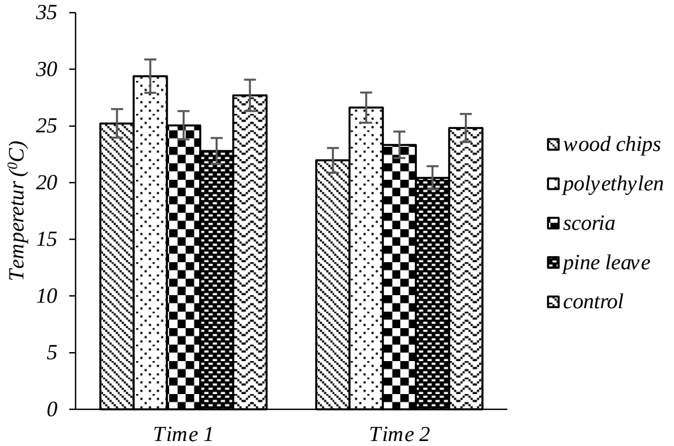

Fig. 5. Effects of mulch types on soil temperature at different sampling times

4. Discussion

Mulching is the practice of covering the soil with natural resources and provide some environmental and aesthetic benefits to the environment (Khan *et al*., 2015). The effect of mulches varies depending on the types of mulches. For example, they work differently to increase the soil temperature in winter and decrease the soil temperature in summer (Mounika *et al*., 2019). Therefore, knowing the performances and interactions of different mulches with different plants is important (Siwek *et a*l., 2015, Kader *et al*., 2017). Compared to other mulch types, plastic mulches are completely impermeable to water and prevent direct evaporation of moisture from the soil, thereby reduces water loss and soil erosion on the surface. Mulches also improve the soil properties by improving the moisture retention capacity, releasing different nutrients and enhancing the biological activities. Therefore, with the improvement of soil properties, plants grow better (Lordan *et al*., 2015).

Soil temperature plays an important role in plant growth. Soil temperature affects two factors, the first is a direct effect on root activity which can be in an optimum temperature range, and the second is an indirect effect on water evaporation which affects the plant growth (Greenly and Rakow, 1995). It can be said that the main factor affecting the temperature of the soil under the mulch is the amount of sunlight absorbed by the mulch types with the same thickness, and this factor is mainly affected by the mulch color. The lighter the color of the mulch, the lower the amount of sunlight absorbed and the lower the mulch temperature would be. In the present study, the presence of black polyethylene mulch decreased the soil temperature due to the absorption of more solar energy than the three mulches of scoria, pine leaves and wood chips in warm months of the year and these findings correspond by the findings of Greenly and Rakow (1995) on the effect of mulch color on soil temperature.

In this study, the application of various mulches had positive effects on weed control. This is in line with the findings of other researchers. Sharma and Sharma (2019) in a study on snow queen stated that mulching led to lower soil temperatures and increased the soil moisture compared to the control, due to the presence of shade, which consequently reduced the photosynthesis and growth of weeds. Also under the treatment with mulches, vegetative plant organs will be weakened and negatively affected due to the production of toxins, increasing the soil temperature due to the decomposition of soil organic matter, and also by increasing the CO2 concentration under the mulches (Sharma and Sharma, 2019).

Application of the mulches in the present study preserved the soil moisture and these findings confirmed the findings of Greenly and Rakow (1995). Greenly and Rakow (1995) reported that in addition to lowering the temperature of the soil, the mulches reduce evaporation from the soil as they impede the transfer of the water vapor from the soil to the air and preserve the soil moisture. The mulch layer reduces the evaporation by creating a separating layer between the ambient air and the indoor air.

In this study, the plants' height increased in the presence of different mulches compared to the control of no-mulches cultivated plants. Increasing the plant height under the treatment with straw mulch may be due to better maintaining the moisture in the soil, which improves the photosynthesis and nutrient uptake by the plants. Production of apical stem meristems increases the plants' height; however, the production of meristem cells under the drought stress reduces and consequently decreases the height of the plants (Dayo-Olagbende *et al*., 2019).

Mulches have many other positive effects on soil and plants. Mulches increase the fresh and dry weight of the roots and branches and improve the number of nodes, leaves and lateral branches by improving the plant growth conditions, which in turn increases the plant biomass and general health. The results of this research on the overall health of the Blanket flower in the presence of mulch types confirm the results of Craig and Schutsky (2009).

In this study, the greenness and vitality of Blanket flower increased in the presence of different types of wood chips and scoria mulches compared to the control treatments. Water deficiency can damage the pigments and plastids, reduce the chlorophyll and carotenoid contents, and reduce the thylakoid thickness in most of the plants (Hossain *et al*., 2010). Also, the decrease in the chlorophyll concentration under the drought stress was attributed to the activity of chlorophyllase, peroxidase, and phenolic compounds and finally to chlorophyll degradation. Therefore, preserving soil moisture due to reduced evaporation of soil surface preserves the photosynthesis and plant growth and prevents the damage to the pigments. The increase in the chlorophyll content after application of the mulches which was observed in the current study has been also confirmed by Follows and Boyer (1996).

The fresh and dry weight of the plants increased in the presence of polyethylene and pine leaf mulches. It appears using the mulches affect the root nutrient uptake. They also indirectly affect plant growth by increasing the activity of the soil microorganisms. The use of mulches has been reported to prevent temperature fluctuations in soil depths of 20-30 cm. This temperature balance, in turn, improves the root growth (Lamont & Bartol, 2004). Therefore, in general, these factors improve plant growth and dry weight after treatment with mulches increase.

In this study, using fresh pine leaf mulch increased the root and shoot fresh weight of the plants. All the vegetative plant organs had increased growth after the mulch treatments. It seems that maintaining the soil moisture and the temperature balance in the root environment as the mulch treatment effects allows the plants to enhance their quality and growth. In an experiment conducted in the Cold Atlantic region, it was reported that sweet corn had higher total biomass yield under the plastic mulch treatments than the non-mulch treatments (Kwabiah, 2014).

The treatment with mulches in the cultivation of Blanket flower also improved the water use efficiency in this plant. Daniele *et al*. (2019) reported that any factor that could enhance the performance of the plants and the seedlings, and reduce the evapotranspiration and improve the leaf gas exchange activity after an irrigation period is effective in increasing the water use efficiency (Daniele *et al*., 2019). In their study on the effect of mulches on growth and yield of cantaloupe (*Cucumis melo* var. *Reticulatus*) was found that using plastic mulch in addition to increasing the weed yield and controlling the weeds effectively, reduced the number of irrigation intervals. Our findings on water use efficiency of Blanket flower in this study confirmed the results of Jafari *et al*. (2005).

In this study, the application of polyethylene mulch reduced the number of days until the first flower emerged and the application of organic mulches of pine leaf and wood chips increased the flowering period. Similar to our results, the results of Kazemi and Safari (2018) also on the application of mulches on Zinnia showed that mulching led to early flowering and long-lasting flowers.

The current research work has practical implementations for arid landscape development in Iran and other countries. Also, further research using a mix of other landscape plants and mulches in other arid regions of the world is recommended.

5. Conclusion

The results of this study showed that the application of all mulch types increased plant growth parameters, decreased the percentages of weeds, accelerated the flowering time and increased the flowering period in the important landscape plant of *Gaillardia* sp. The highest water use efficiency was related to the application of the polyethylene, pine leaf, and wood chips mulches, respectively. The outcome of this research work on the water-conserving ornamental-medicinal plant of *Gaillardia* sp. in combination with mulches can assist in more sustainable landscaping in arid urban environments.

References

Ahrar, M., M. Delshad, M. Babalar, 2009. Improving water/fertilizer use efficiency of hydroponically cultured greenhouse cucumber by grafting and hydrogel amendment. Horticultural Science, 23; 69-77.

Cregg B.M., R. Schutzki, 2009. Weed control and organic mulches affect physiology and growth of landscape Shrubs. Horticulture Science, 44(5); 1419–1424.

Daniele, M., S. Benvenuti, S. Cacini, S. Lazzereschi, G. Burchi, 2019. Effect of hydro-compacting organic mulch on weed control and cropperformance in the cultivation of three container-grown ornamental shrubs: Old solutions meet new insights. Scientia Horticulturae, 252; 260-267

Dayo-Olagbende, G.O., B.S. Ewulo, O.O. Akingbola, 2019. Combined effects of tithonia mulch and urea fertilizer on soil physico-chemical properties and maize performance. Journal of Sustainable Technology, 10(1); 86-93.

Dere, S., T. Günes, R. Sivaci, 1998. Spectrophotometric determination of chlorophyll-a, b and total carotenoid contents of some algae species using different solvents, Turkish Journal of Botany, 22; 7–13.

Farooq, M., A. Wahid, N. Kobayashi, D. Fujita, S. M. A. Basra, 2009. Plant drought stress: effects, mechanisms and management.Agronomy for Sustainable Development, 185-212.

Follows, R.J., J.S. Boyer, 1996. Structure and activity of chloroplast of sunflower. Leaves having various water potentials.Planta, 132; 229-239.

Greenly, K. D., A. Rakow, 1995. The effect of wood mulch type and depth on weed and tree growth and certain soil parameters.Journal of Arboriculture, 21(5); 225-232.

Hossain, M. I., A. Khatun, M. S. A.Talukder, M. M. R. Dewan, M. S. Uddin, 2010. Effect of drought on physiology and yield contributing characters of sunflower. Bangladesh Journal of Agricultural Research, 35(1); 113-124.

Iies, J.K., M.S. Dosmann, 1999. Effect of organic and mineral mulches on soil properties and growth of fairview flame® red maple trees. Journal of Arboriculture, 25(3); 163-167.

Jaafari, P., H. Mollahoseini, M. Seilsepoor, 2005. Investigation of planting pattern of melon in traditional method and cultivation using plastic mulch. Journal of Research in Agricultural Sciences, 2 (2); 61-71, (In Persian).

Kader, M. A., M. Senge, M.A. Mojid, K. Ito, 2017. Recent advances in mulching materials and methods for modifying soil environment. Soil & Tillage Research, 168(5); 155–166.

Kazemi, F., S. Beecham, J. Gibbs, 2011. Streetscape biodiversity and the role of bioretention swales in an Australian urban environment. Landscape and Urban Planning, 101; 139–148.

Kazemi, F., N. Safari, 2018. Effect of mulches on some characteristics of a drought tolerant flowering plant for urban landscaping. Desert, 23 (2); 75-84.

Khan, S., M. Pal, V. Kumar, 2015. Influence of different mulches on growth and yield of sponge gourd (*Luffa clyndrica* L.). Plant Archives, 15(1); 393-395.

Kwabiah, A.B., 2004. Growth and yield of sweet corn cultivars in response to planting date and plastic mulch in a short season environment. Scientia Horticulturae, 102 (2); 147-166.

Lamont, W.J., J.W. Bartol, 2004. Production of vegetables, strawberries, and cut flowers using plastic culture. Natural Resource, Agriculture, and Engineering Service (NRAES). Ithaca.

Lordan, J., M. Pascual, J. M. Vilar, F. Fonseca, J. Papio, V. Montilla, 2015. Use of organic mulch to enhance water-use efficiency and peach production under limiting soil conditions in a three-year-old orchard. Spanish Journal of Agricultural Research, 13 (4); e0904.

Marcum, K.B., 1998. Cell membrane thermo-stability and whole-plant heat tolerance of Kentucky. Crop Science, 38; 1214-1218.

Mounika, T., T. Kiran Patro, N. Emmanuel, B. Chennakesavulu, S. Suneetha., M. L. Narayana Reddy., 2019. Effect of mulches on growth and yield parameters in gherkin (Cucumis sativus sub spp. Anguria). International Journal of Chemical Studies, 7(2); 1711-1713.

National Centers for Climatology, 2019, Climate information of the city of Mashhad, available on: https://www.ncdc.noaa.gov/climate-information, access date: 2019.07.25.

Pakdel, p., Tehranifar, A., Nemati, S. H., Lakzian, A. 2011a. Application of different types of mulch on some traits of growth of two cultivars of parsley in Mashhad shrub. Journal of Crop Production and Processing. 13, 197-204. (in Persion).

Pakdel, p., Tehranifar, A., Nemati, S. H., Lakzian, A. 2011b. Effect of four types of mulches including wood chips, municipal compost, sawdust and gravel in three different thickness on the growth of *Platunus Orientalis* L. Journal of Horticulture Science, 25 (3): 296-303 (in Persian).

Salehi sardoei, A., S. Shahmoradzadeh Fahraji, H. Ghasemi, 2014. Effects of different growing media on growth and flowering of zinnia (*Zinnia elegans*). International Journal of Advances in Biology and Biomedical Research, 2; 894-1899.

Salim, R., R.A. El-Halawa, 2002. Efficiency of dry plant leaves (mulch) for removal of lead, cadmium and copper from aqueous solutions. Process safety and environmental protection, 80; 270-276.

Salter, P.J., F. Haworth, 1961. The available water capacity of a sandy loam soil: I. A critical comparison of methods of determining the moisture content of soil at field capacity and at the permanent wilting percentage. Journal of Soil Science, 12; 326-334.

Shaban, M., S. Mansoorifar, M. Ghobadi, S.H. Sabaghpoor, 2012. Figures physiological characteristics of chickpea (*Cicer arietinum L.*) under water stress and nitrogen fertilizer primers. Grain Management, 3; 53-66.

Singer, C.K., C.A. Martin, 2008. Effect of landscape Mulches on Desert Landscape Microclimates. Arboriculture & Urban Forestry, 34(4); 230-237.

Siwek, P., I. Domagała-Świątkiewicz, A. Kalisz, 2015. The influence of degradable polymer mulches on soil properties and cucumber yield. Agrochimica, 59 (2); 108–123.

Sharma, S., D.P. Sharma, 2019. Weed management in stone fruit nectarine orchard with inorganic mulches and herbicides. Journal of Indian Weed Science, 51(1); 45–49.

Salve, S., SG, B., Gawade, N., Nilwarn, Y., 2019, Performance of promising genotypes of gaillardia (*Gaillardia pulchella* L.) for yield attributes and storage study, Journal of Pharmacognosy and Phytochemistry, 8(3): 1032-1034.

Whittinghill, L., B. Rowe, M. Ngouajio, B. Cregg, 2016. Evaluation of nutrient management and mulching strategies for vegetable production on an extensive green roof. Agroecology and Sustainable Food Systems, 40(4): 297-318. http://dx.doi.org/10.1080/21683565.2015.1129011.

Zhao, H., R.Y. Wang, B. L. Ma, Y.C. Xiong, S. C. Qiang, C.L.Wang, 2014. Ridge-furrow with full plastic film mulching improves water use efficiency and tuber yields of potato in a semiarid rainfed ecosystem. F Crop Res, 161; 137–148.