Acta Sci. Pol. Hortorum Cultus, 16(4) 2017, 127–139

www.acta.media.pl ISSN 1644-0692 DOI: 10.24326/asphc.2017.4.13

ORIGINAL PAPER

Accepted: 25.04.2017

EFFECT OF ORGANIC MULCHES ON DEVELOPMENT OF THREE ORNAMENTAL ANNUAL PLANTS, MOISTURE AND CHEMICAL PROPERTIES OF SOIL

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ABSTRACT

The objective of the research was to investigate the effects of pine bark, fresh grass and peat mulch on the ornamental value of *Petunia* × *atkinsiana*, *Impatiens walleriana* and *Tagetes patula* cultivars during the short growing period, and soil chemical properties (electrical conductivity, pH, organic matter, total N, P, K, Ca, Mg) and soil moisture in the second year in a temperate climate. Results show that fresh grass and peat mulch increased plant height of *Petunia* and *Impatiens* from 40 days after planting until the end of experiment. During the same period plant diameter of *Impatiens* and *Tagetes* was enhanced in all studied mulches, but plant diameter of *Petunia* was enlarged only with peat mulch. *Impatiens* number of flowers enhanced in all mulches, but in case of *Tagetes* the number was higher with pine bark. In comparison with unmulched treatment, soil moisture, electrical conductivity and pH increased in fresh grass and pine bark treatments. Soil Mg content was higher up to 15% in plots with fresh grass mulch. Plant diameter of all species was positively correlated with soil electrical conductivity.

Key words: fresh grass, pine bark, peat, *Petunia* × *atkinsiana, Impatiens walleriana, Tagetes patula*

INTRODUCTION

The problems of plant cultivation in urban areas frequently relate to soil properties which are altered by human activities [Lorenz and Lal 2009]. The requirements of quality parameters for urban soil depend on the purpose of soil usage [Vrščaj et al. 2008]. For example, ornamental bedding plants and wild herbaceous vegetation require different levels of nutrients and water-holding capacity in growing media.

In urban landscape, ornamental bedding plants usually grow over large areas, which need continuous maintenance. Additional watering and multiple fertilizer applications are essential for promoting a higher ornamental value of these plants over the short growing period. Soil surface mulching is one of the ways to increase water-holding capacity. Several agricultural and industrial wastes have been used as mulches in horticulture. Plant residues are sometimes used as mulch in decorative plant beds in order to provide optimal growing conditions for plants with minimal maintenance costs. Plant mulching in managed landscape is commonly used to suppress weeds and reduce soil evaporation. Mulching also improves plants growing media properties, which can positively influence plant growth and flowering during the growing season. Cabilovski et al. [2014] reported that different composts mixed with the topsoil are used to improve soil fertility. On the other hand, mulch as a source of nutrients for urban plants is less preferred. It has been proven that with different organic mulch-

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es it is possible to improve soil physical properties [Olasantan 1999, Sønsteby et al. 2004, Mulumba and Lal 2008, Velykis et al. 2014] and increase soil nutrient content [Tiquia et al. 2002, Fang et al. 2008]. However, some carbon-rich organic materials as bark and wood chips, often used in ornamental landscapes, stimulate the activity of microbes in the soil and can cause nitrogen deficiency [Winter et al. 1999, Sønsteby et al. 2004, Miller and Seastedt 2009]. Nitrogen deficiency caused by mulching generally can decrease the growth of plants with roots spread at 0–15 cm depth, because of the competition between microbes and plants for the available nitrogen in the soil. In contrast, fresh grass mulch has a low carbon-to-nitrogen ratio [Bary et al. 2005, Moyin-Jesu 2007]. Such materials decompose rapidly and increase soil microbial biomass and organic matter [Tiquia et al. 2002].

Mulching with different organic materials can increase plant biomass production and yields of different crops. For example, the herb and essential oil yields in geranium (*Pelargonium graveolens* L'Hér.) were positively influenced by paddy straw mulch [Ram et al. 2003]. Zhao et al. [2014] reported the increasing effect of sunflower (*Helianthus annuus* L.) height and leaf area index by straw mulch. The length of flower stem of *Acidanthera bicolor* var. *murielae* Perry was enhanced by pine bark and peat mulch [Kocira and Laskowska 2006]. Root parameters can also be influenced by mulching, as was found in a study by Kumar and Dey [2011], where hay mulch increased strawberry (*Fragari*a × *ananassa* Duch.) yield and such root growth density parameters as length, mass and volume.

Opposite results were shown by Sønsteby et al. [2004], where significantly higher strawberry yield was found in unmulched plots, compared to pine bark mulched areas. All these studies showed that mulching effects depend on mulching material and plant species.

Many annual bedding plants are sensitive to growing conditions and some organic mulches may probably increase flowering and growth through the improvement of soil chemical balance and water availability in the short growing season. It could help to decrease or even cancel additional watering and multiple fertilizer applications in urban landscapes and keep the environment ecologically cleaner. Mulching short-living bedding plants with fresh grass and pine bark could provide an opportunity for utilization of these organic wastes. Comparison with peat mulch gives an indication of the possibility of using these mulches as an alternative or substitute for peat mulch.

A frequently used design conception is to grow together shrubs and perennials over urban areas. The long term effects of organic mulches have mainly been studied on landscape woody plants [Iles and Dosmann 1999, Downer and Hodel 2001, Fang et al. 2008]. Less information can be found about the influence of organic mulches on herbaceous landscape plants, especially annual ornamental bedding plants, which are used in short growing season. The current work's hypothesis is that mulching decreases fertilizing and watering reguirements of annual ornamental bedding plants and improves their growth and flowering. The objective of this research was to determine the effects of different mulching materials (fresh grass, pine bark, peat) on annual ornamental bedding plants growth, flowering and biomass production during the short growing period, and soil moisture and chemical properties in the second year in a temperate climate.

MATERIALS AND METHODS

Experimental site. The field experiments were carried out from June to August in 2004 and 2005 in the experimental garden of Estonian University of Life Sciences (58º41'N, 25º55'E). The soil type of the experimental area was sandy loam with homogeneous fertility and high humus content (3%). Before planting, soil test values indicated the pH range from 6.2 to 6.4, 0.20% of total nitrogen, very high available P (160 mg kg^{-1}) and adequate available K (120 mg kg^{-1}) amounts for optimum growth of the studied species. No additional fertilizers were added to the soil before planting.

During both experimental years and periods (June 15 – August 25), the precipitation amount was lower, compared to the 10-year average (fig. 1). In comparison with the first year study period, the precipitation amount of the second year decreased to 24.8 mm and was higher only in the first 10-day period of August.

In 2004 and 2005, the average monthly air temperatures were, respectively, 14.3 and 15.3°C in June, 17.4 and 19.5°C in July, 17.6 and 16.7°C in August. The average temperatures in Estonia in the 10-year period were, respectively, 15.6°C in June, 17.9°C in July and 17.6°C in August. It appears that compared to the 10-year average, the temperature in 2004 was higher from July 20 to the end of the experiment, while in 2005 the temperature was lower from July 24 to August 15.

Treatments, plant culture and growing conditions. The experiment was carried out, in both years, from the middle of June, on the same location with new plants and renewed mulching materials. Mulches were removed in the end of first experiment before collecting of the plants. In next experimental year, new plants were planted out on the same location and plots were covered with new mulching materials. A randomized complete block design was used with three types of mulches. The experimental treatments were as follows: unmulched (control), pine (*Pinus sylvestris* L.) bark mulch, fresh grass mulch and peat mulch. The chemical characteristics of the mulching materials used during the experiments showed that the N content ranged from 0.69% to 3.65%, C from 15 to 72%, P from 0.03 to 0.05%, K from 0.01 to 1.02%, Ca from 0.54 to 1.39% and Mg from 0.16 to 0.25% (tab. 1). Fresh grass had the highest N, P, K and Mg contents. The pH range was between 3.3 and 5.8, fresh grass mulch had the highest pH.

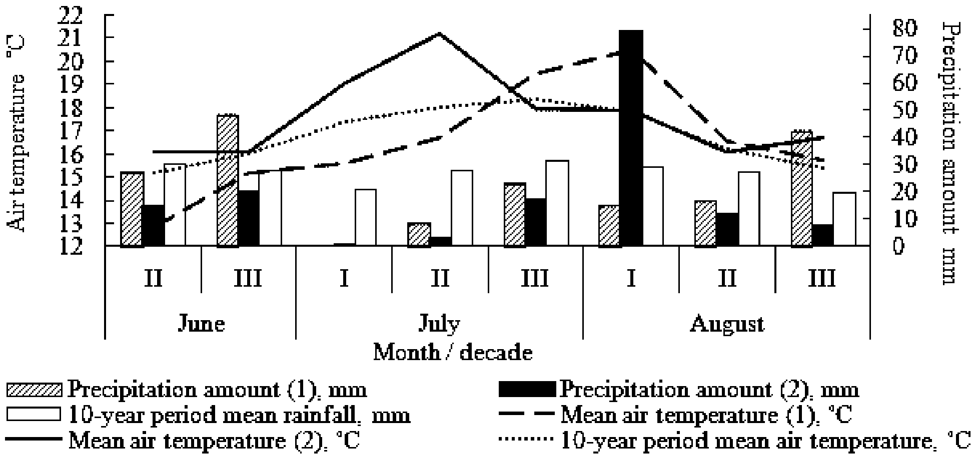

Fig. 1. Average air temperature and total precipitation in 2004 (1), 2005 (2) and 10-year period

Table 1. Chemical characteristics of the mulching materials used in the experiments

Mulching materials	pH	C	N	P	K	Ca	Mg
		(%)					
Fresh grass	5.8	15	3.65	0.05	1.02	0.54	0.25
Pine bark	3.9	72	0.69	0.03	0.05	1.39	0.17
Peat	3.3	45	1.02	0.03	0.01	0.61	0.16

Garden Petunia (*Petunia* × *atkinsiana* (Sweet) D. Don ex W.H. Baxter) 'Sonja Blue', Busy Lizzie (*Impatiens walleriana* Hook.f.) 'Candy Carmine' and French Marigold (*Tagetes patula* L.) 'Disco Golden Yellow' were used as annual plants for the experiments. The plants were pre-grown in a greenhouse from seeds in fertilized peat-based substrate with one transplanting in two true leaf stage. No additional fertilizing during plants growth was done. The plants were hardened off before planting outside and planted out to the experimental plots on June 15, after the period of possible night frosts. The distance between the plants was 30 cm from each side. Three replications (plots) for each treatment, and six plants of each culture for each replication were used. Plots of 0.9 × 1.8 m were randomly distributed. All plots had one border row of the same plants. Mulches were applied after planting, in a 5 cm thick layer. Fresh grass biomass was harvested after mowing and immediately applied to the plots annually according to the treatment design. All plants were fertilized once during the vegetative period with a 0.2% solution of the complex fertilizer with NPK 14-5-21 at 0.5 dm^3 per plant 25 days after planting. During both experimental years no additional watering was done. The weeds were controlled manually over the growing season. At the end of the experiments the plants and mulching materials were collected.

Measurements and analyses. During both experimental years the plant height (cm) and diameter (cm), number of flowers and flower diameter (cm) were measured. Plant height and diameter were measured from the highest and widest point of all tested plants five times at 10-day intervals, starting from 30 days after planting outside. The number of flowers from each plant and replication was counted at the end of the experiment. The flower diameter of 10 flowers from each replication was determined five weeks after planting, once in the full flowering period.

To evaluate the influence of mulches on plant biomass production, the dry weight of leaves and roots (g) was measured at the end of both experiments. The plants were harvested 70 days after planting, before possible night frosts. The dry weight of the plant parts was determined after drying to constant weight at 70°C in the drying oven ("Memmert", Schwabach, Germany).

To assess the effect of mulches on soil properties, the soil moisture (%), electrical conductivity (dS m^{-1}), pH_{KCl}, organic matter (%), total N (%), P (mg kg^{-1}), K (mg kg^{-1}), Ca (mg kg^{-1}) and Mg (mg kg^{-1}) were determined over the second year. The soil moisture and electrical conductivity (EC) were measured by the WET Sensor WET-2 ("AT Delta-T Devices", Cambridge, England) five times during the experiment at two-week intervals. Before the plant harvest, the soil samples were collected from all replications for all species at 0–15 cm depth. The air-dried samples were sieved through a 2-mm sieve and used to determine the soil organic matter, pH, total N, available P, K, Ca and Mg. The soil pH was measured with a glass electrode in a suspension of soil in a solution of 1 M KCl by SG2 SevenGo pH Portable Meter ("Mettler-Toledo", Columbus, USA). The total nitrogen content was determined using the Kjeldahl method [Bremner and Mulvaney 1982]. The content of available phosphorus, potassium, calcium and magnesium in soil was determined by the Mehlich-3 method [Soil and Plant Analysis Council 1992]. The soil organic matter was analyzed by mass loss on ignition at 500°C for 3 h and measured as percent mass loss.

Chemical analysis of mulching materials was carried by following methods: total carbon by Tjurin method [Vorobyova 1998], total nitrogen by Kjeldahl method, total P, K, Ca and Mg by mineralization in the mixture of acids (HNO_3+$HClO_4$) [Haynes 1980]. The pH of the different mulches was measured with a glass electrode in a suspension of soil in a solution of 1 M KCl by SG2 SevenGo pH Portable Meter ("Mettler-Toledo", Columbus, USA).

Statistical analysis. A one-way analysis of variance (ANOVA) was conducted to compare the plant height, plant diameter, number of flowers, flower diameter, leaf and root dry weight, soil moisture and chemical parameters between treatments. To evaluate the significant influence, the least significant difference (LSD 0.05) was calculated. Linear correlation coefficients were calculated between variables, with the significance of the coefficients being $P \leq 0.01^{**}$, $P \leq 0.05^{*}$. Correlation analysis were performed to detect relations between different soil parameters, plant characteristics and soil parameters.

RESULTS

Plant growth and flowering. Compared to the control treatment, fresh grass and peat mulch increased significantly the height of *Petunia* plants from 40 to 50 days after planting and at the end of both seasons (fig. 2). However, pine bark enhanced the plant height at the end of seasons. In the end of both seasons, the differences between peat, fresh grass, pine bark and unmulched treatments reached up to 30%, 26%, 20% in 2004 and 13%, 12%, 13% in 2005, respectively.

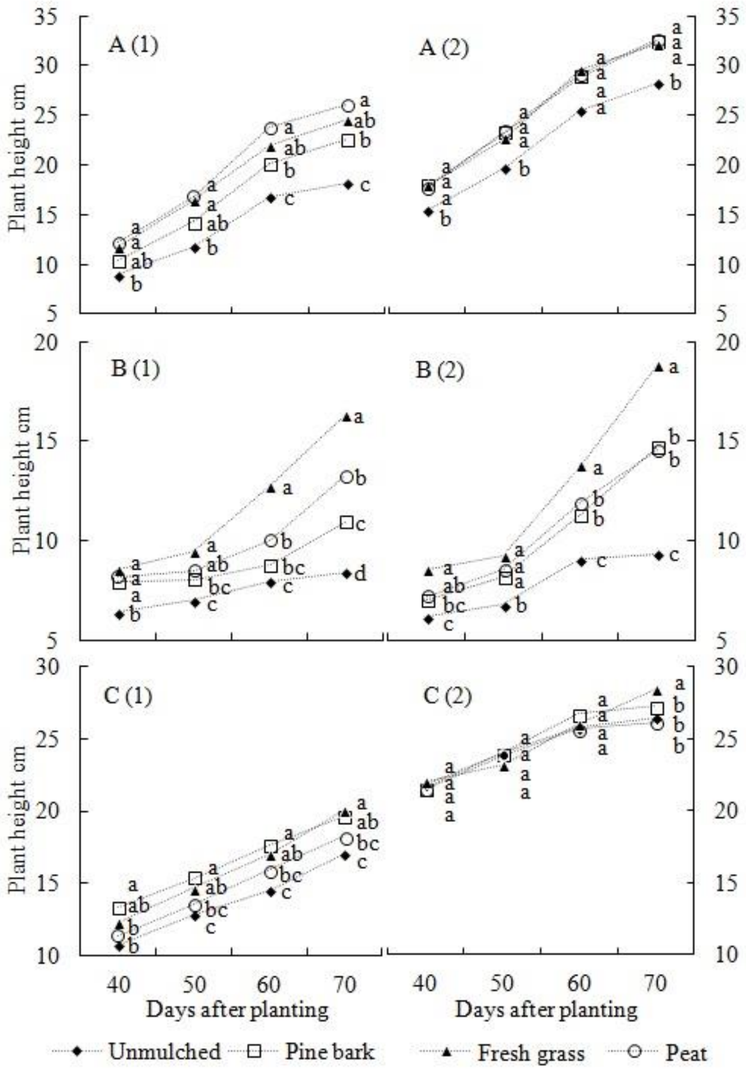

Fig. 2. Effect of mulching treatments on plant height of *Petunia* × *atkinsiana* 'Sonja Blue' (A), *Impatiens walleriana* 'Candy Carmine' (B) and *Tagetes patula* 'Disco Golden Yellow' (C) plants in 2004 (1) and 2005 (2). Means followed by different letters in the same figure for 10-days period after planting separately are significantly different ($P < 0.05$) according to LSD test

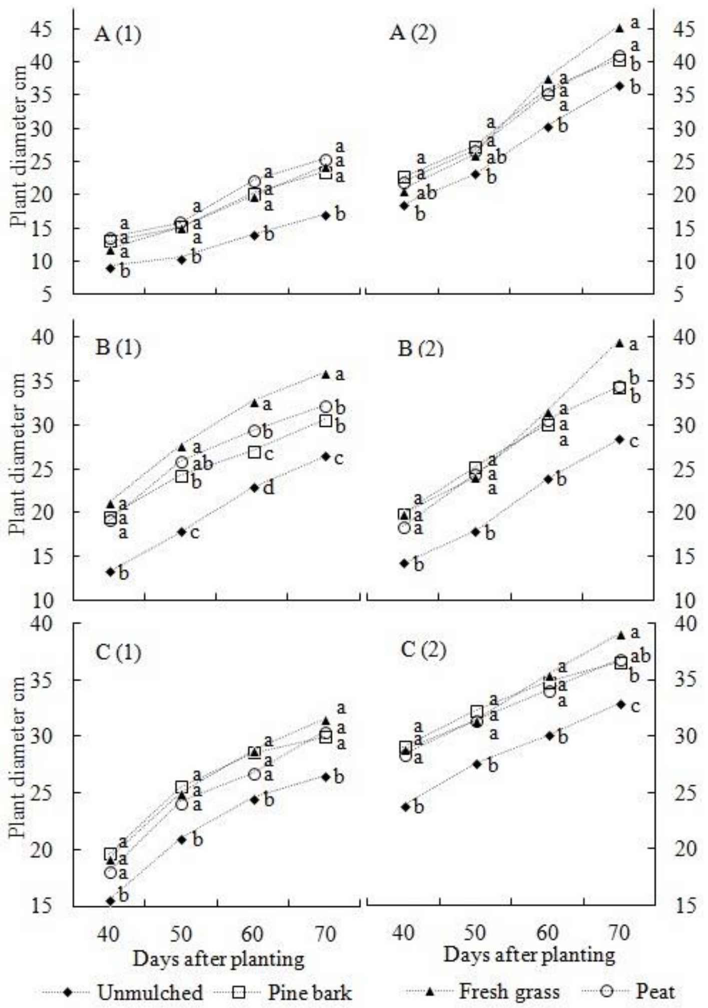

Fig. 3. Effect of mulching treatments on plant diameter of *Petunia* × *atkinsiana* 'Sonja Blue' (A), *Impatiens walleriana* 'Candy Carmine' (B) and *Tagetes patula* 'Disco Golden Yellow' (C) plants in 2004 (1) and 2005 (2). Means followed by different letters in the same figure for each 10-days period after planting separately are significantly different (P < 0.05) according to LSD test

Impatiens plants were higher on the plots mulched with fresh grass and peat mulches from 40 to 70 days after planting in both seasons compared to unmulched treatment. Pine bark mulch increased the plant height of *Impatiens* compared to control plots at the end of experiments. Among all treatments, the highest plants grew in the plots with fresh grass mulch; the mean differences between fresh grass and control treatments at the end of 2004 and 2005 were 7.9 cm and 9.5 cm, respectively. In the end of both seasons, the differences between fresh grass, peat, pine bark and control treatments reached up to 48%, 37%, 23% in 2004 and 51%, 36%, 37% in 2005, respectively.

The plant height of *Tagetes* was significantly enhanced by pine bark and fresh grass mulch from 50 to 70 days after planting in 2004, compared to the treatment without mulch, with final heights of 19.6, 20.1 and 17.0 cm, respectively. In 2005, the only difference between the unmulched (26.5 cm) and fresh grass (28.4 cm) treatments appeared at the end of the season.

The plant diameter of *Petunia* was significantly increased by peat mulch starting 40 days after planting in 2004 and 2005 compared to unmulched treatment, with the mean differences 8.2 and 4.6 cm, respectively (fig. 3). In both years, pine bark enhanced the plant diameter of *Petunia* 40 to 50 days after planting, compared to control plots, but fresh grass mulch 60 to 70 days after planting, also compared to control plots. In the end of both seasons, the differences between fresh grass, peat and control treatments reached up to 30%, 33% in 2004 and 20%, 11% in 2005, respectively.

Impatiens plants were wider in the plots mulched with pine bark, fresh grass and peat material from 40 days after planting in both seasons, compared to the treatment without mulch. In the end of both seasons, the differences between fresh grass, peat, pine bark and unmulched treatments reached up to 27%, 18%, 14% in 2004 and 28%, 17%, 18% in 2005, respectively. Compared to all other treatments, *Impatiens* plants were wider in plots with fresh grass mulch in the end of both seasons. The mean differences between fresh grass and control treatments at the end of 2004 and 2005 were 9.5 cm and 11.1 cm, respectively.

Tagetes plants diameter was significantly increased by pine bark, fresh grass and peat mulch 40 days after planting, in both growing seasons, compared to unmulched treatment. In the end of both seasons, the differences between fresh grass, peat, pine bark and control treatments reached up to 16%, 13%, 11% in 2004 and 16%, 11%, 10% in 2005, respectively.

Table 2. Effect of mulching treatments on the number of flowers and flower diameter of *Petunia ×atkinsiana* 'Sonja Blue', *Impatiens walleriana* 'Candy Carmine' and *Tagetes patula* 'Disco Golden Yellow' plants in 2004 and 2005

Plant	Treatment	2004		2005	
		number of flowers	flower diameter (cm)	number of flowers	flower diameter (cm)
Petunia × atkinsiana	unmulched	4.3b	5.75ab	6.7a	6.33b
	fresh grass	6.7ab	5.83a	7.2a	6.48ab
	pine bark	5.8b	5.50b	7.6a	6.52ab
	peat	8.9a	5.90a	7.4a	6.33b
Impatiens walleriana	unmulched	9.8b	4.97a	12.7c	4.60c
	fresh grass	19.2a	4.97a	18.0ab	4.82ab
	pine bark	18.0a	4.83a	19.9a	4.75bc
	peat	18.2a	4.93a	16.3b	4.97a
Tagetes patula	unmulched	11.0b	5.47c	19.8b	5.18c
	fresh grass	14.2ab	5.77ab	24.0a	5.37b
	pine bark	14.7a	5.87a	24.0a	5.62a
	peat	13.6ab	5.73abc	25.6a	5.68a

Means followed by different letters in the same column for each species separately are significantly different ($P < 0.05$) according to LSD test

Petunia had significantly more flowers in the peat treatment in 2004, compared to the control treatment, with mean values 8.9 and 4.3, respectively (tab. 2). The number of *Impatiens* flowers was higher in all mulched treatments in both seasons, the differences between fresh grass, pine bark, peat and unmulched treatments reached up to 49%, 46%, 46% in 2004 and 29%, 36%, 22% in 2005, respectively. The number of *Tagetes* flowers was increased by pine bark in both years, compared to the control treatment, the differences reached up to 25% in 2004 and 18% in 2005. Number of flowers of *Tagetes* in the plots with peat and fresh grass mulch was 23% and 18% higher in 2005, respectively, compared to the unmulched treatment.

Mulching had no influence on *Petunia* flower diameter (tab. 2). The flower diameter of *Impatiens* was increased by fresh grass and peat mulches in 2005, compared to the control treatment, with mean values 4.8, 5.0 and 4.6 cm, respectively. *Tagetes* flowers were wider in plots with fresh grass and pine bark mulches, in both seasons, compared to the unmulched treatment. The differences between fresh grass, pine bark and control treatments reached up to 5%, 7% in 2004 and 4%, 7% in 2005, respectively.

Table 3. Pearson's correlation between plant characteristics (plant height (cm) and diameter (cm); number of flowers; leaf and root dry weight (g) values) and soil parameters (soil moisture (%); electrical conductivity (EC) (dS m^{-1}); pH); between plant characteristics and flower diameter (cm) and number of flowers of *Petunia × atkinsiana* 'Sonja Blue', *Impatiens walleriana* 'Candy Carmine' and *Tagetes patula* 'Disco Golden Yellow' plants in 2005

Characteristics	Soil moisture (%)	Soil EC (dS m^{-1})	Soil pH	Flower diameter (cm)	Number of flowers
Petunia × atkinsiana					
Plant height (cm)	0.491	0.529	0.554	0.353	0.355
Plant diameter (cm)	0.369	0.598*	0.592*	0.039	0.446
Number of flowers	0.281	0.274	0.263	0.115	1.000
Leaf dry weight (g)	0.555	0.389	0.470	–0.390	0.098
Root dry weight (g)	0.392	0.229	0.215	–0.424	0.466
Impatiens walleriana					
Plant height (cm)	0.635*	0.603*	0.350	0.383	0.657*
Plant diameter (cm)	0.678*	0.784**	0.399	0.485	0.598*
Number of flowers	0.789**	0.425	0.221	0.571	1.000
Leaf dry weight (g)	0.489	0.756**	0.596*	0.115	0.322
Root dry weight (g)	0.550	0.266	0.014	0.579*	0.478
Tagetes patula					
Plant height (cm)	0.285	0.592*	0.459	0.031	0.364
Plant diameter (cm)	0.682*	0.702*	0.423	0.396	0.780**
Number of flowers	0.634*	0.279	0.000	0.509	1.000
Leaf dry weight (g)	–0.275	0.194	0.327	–0.575	–0.490
Root dry weight (g)	0.139	0.567	0.233	0.211	0.096

*, ** Indicate significance levels: $P \leq 0.05$ ($p = 0.576$), $P \leq 0.01$ ($p = 0.708$), respectively; N = 10

The correlation analysis indicated that the relation between the plant characteristics and soil parameters differed with different species (tab. 3). The soil EC and pH influenced the plant diameter of *Petunia*. The soil moisture and EC were positively correlated with the plant height of *Impatiens* as well as the plant diameter of *Tagetes*. In addition, a positive correlation appeared between the soil EC and the plant height of *Tagetes*. The soil moisture and EC were positively correlated with the plant diameter of *Impatiens*. The soil moisture also influenced the number of flowers of *Impatiens* and *Tagetes*.

Leaf and root dry weight. Mulching had no influence on the leaf dry weight of *Petunia* and *Tagetes* (tab. 4). The leaf dry weight of *Impatiens* was significantly increased by fresh grass and pine bark mulch in 2005, compared to unmulched treatment. Between all studied mulches, the dry weight of leaves was greater in the fresh grass treatment. The leaf dry weight in the fresh grass, pine bark and peat treatments was 45%, 31% and 20% higher, respectively, than in the control treatment. The leaf dry weight of *Impatiens* was positively correlated with the soil EC and pH (tab. 3).

The significantly greater root dry weight of *Petunia* plants was obtained in peat and pine bark mulching treatment in 2005, compared to unmulched treatments, and the differences reached up to 34% and 22%, respectively (tab. 4). The root dry weight of *Impatiens* was enhanced by fresh grass and peat mulch, in both experimental seasons, compared to treatment without mulch, the differences reached up to 73%, 74% in 2004 and 44%, 47% in 2005, respectively. The root dry weight of *Impatiens* in the pine bark treatment was 41% higher in 2005, compared to control plots. No influence was obtained by mulching on the root dry weight of *Tagetes*.

Table 4. Effect of mulching treatments on leaf and root dry weight of *Petunia ×atkinsiana* 'Sonja Blue', *Impatiens walleriana* 'Candy Carmine' and *Tagetes patula* 'Disco Golden Yellow' plants in 2004 and 2005

Plant	Treatment	Dry weight of plant parts (g)			
		2004		2005	
		leaf	root	leaf	root
Petunia × atkinsiana	unmulched	1.30a	0.60a	4.63b	0.53c
	fresh grass	2.11a	1.16a	5.92ab	0.58bc
	pine bark	1.81a	1.04a	5.59ab	0.68ab
	peat	1.84a	1.04a	5.55ab	0.80a
Impatiens walleriana	unmulched	1.38a	0.67c	3.53d	0.51b
	fresh grass	1.27a	2.44ab	6.36a	0.91a
	pine bark	1.21a	1.40bc	5.08bc	0.86a
	peat	1.16a	2.55a	4.43cd	0.96a
Tagetes patula	unmulched	1.73a	1.15a	8.35a	0.64a
	fresh grass	1.56a	1.25a	8.26a	0.75a
	pine bark	1.71a	1.17a	8.54a	0.74a
	peat	1.71a	1.03a	7.86a	0.72a

Means followed by different letters in the same column for each species separately are significantly different ($P < 0.05$) according to LSD test

Table 5. Effect of mulching treatments on soil moisture, electrical conductivity (EC), pH, organic matter (OM), total nitrogen, P, K, Ca and Mg at 0–15 cm depth in 2005

Treatment	Moisture (%)	EC (dS m^{-1})	pH	OM (%)	N (%)	P (mg kg^{-1})	K (mg kg^{-1})	Ca (mg kg^{-1})	Mg (mg kg^{-1})
Unmulched	11.4b	0.70c	6.6b	7.2a	0.18a	144a	113a	784a	358b
Fresh grass	16.1a	0.89a	6.7a	7.0a	0.18a	151a	154a	783a	423a
Pine bark	16.7a	0.82ab	6.7a	7.4a	0.18a	140a	113a	793a	364b
Peat	14.9ab	0.75bc	6.5b	7.5a	0.19a	142a	89a	768a	362b

Means followed by different letters in the same column are significantly different (P < 0.05) according to LSD test

Table 6. Pearson's correlation between soil parameters (soil moisture (%); electrical conductivity (EC) (dS m^{-1}); pH; Mg; Ca; K and P) in 2005

Characteristics	Moisture (%)	EC (dS m^{-1})	pH	P (mg kg^{-1})	K (mg kg^{-1})	Ca (mg kg^{-1})	Mg (mg kg^{-1})
Moisture (%)	1						
EC (dS m^{-1})	0.589^{**}	1					
pH	0.311	0.754^{**}	1				
P (mg kg^{-1})	0.327^{*}	0.188	–0.096	1			
K (mg kg^{-1})	0.127	0.590^{**}	0.591^{**}	0.249	1		
Ca (mg kg^{-1})	0.240	–0.002	0.015	0.121	0.001	1	
Mg (mg kg^{-1})	0.209	0.311	0.071	0.167	0.050	0.204	1

*, ** Indicate significance levels: P ≤ 0.05 (p = 0.325), P ≤ 0.01 (p = 0.418), respectively; N = 34

Soil moisture and chemical properties. The results of the second year showed that the soil moisture in the fresh grass and pine bark treatments was 29% and 32% higher, respectively, compared to the control treatment (tab. 5). The soil EC was also enhanced by fresh grass and pine bark mulch compared to treatment without mulch and the differences reached up to 21% and 15%, respectively. The soil EC was positively correlated with soil K content, pH and moisture (tab. 6).

Fresh grass and pine bark mulch increased the soil pH (6.7 in both treatments) compared to unmulched (6.6) and peat (6.5) treatment (tab. 5). Mulching had no influence on the amount of organic matter, total nitrogen, P, K and Ca in the soil among all treatments. Fresh grass mulch enhanced the soil Mg content compared to other treatments, and the difference between fresh grass and unmulched treatments reached up to 15%. A positive correlation between the pH and soil K content was observed (tab. 6).

DISCUSSION

Mulch effect on plant growth parameters and flowering. All studied mulches can be used for accelerating growth and flowering of the studied annual bedding plants over the short growing season. In both years, the plant height and diameter of *Petunia* and *Impatiens* and the diameter of *Tagetes* were enhanced by fresh grass, pine bark and peat mulch. The positive influence of mulching on plant growth and development was probably caused by decreased soil temperature, increased soil moisture and ions' concentration under the mulching materials. The decreasing of soil temperature under organic mulches were reported in other studies [Iles and Dosmann 1999]. In the current study, the enhancing effect on plant growth by peat mulch could be explained by a decrease in soil temperature. Reduction of soil temperature by peat mulch was reported by Korotkova and Vabrit [2010], where negative correlation between the soil temperature and plant diameter of *Petunia*, *Impatiens*, *Tagetes* and the plant height of *Petunia* was found. Similarly to soil temperature the increased height and diameter of *Petunia* and *Tagetes* in the second study year could have been caused by higher air temperature in the first half of the year.

The optimal EC of the growing media for all the studied species is 1.5–2.0 dS m^{-1} [Faust et al. 2005]. Consequently, the increased soil EC under the studied mulches became closer to the optimal parameter of the soil EC for all the investigated plant species, compared to the unmulched treatment (0.7 dS m^{-1}). The plant diameter of *Petunia* and the diameter and height of *Impatiens* and *Tagetes* correlated positively with the soil EC. Soil EC probably had a positive effect on plant growth due to the increase of ions' availability in soil. It has been found before that the growth of *I. walleriana* plants increased with soluble salt concentration between 0.5 and 1.0 dS m^{-1} in compost growing media [Klock 1997].

The plant height of *Impatiens*, the plant diameter and number of flowers of *Impatiens* and *Tagetes* were positively correlated with the soil moisture. Blom et al. [2008] reported that *Impatiens* 'Super Elfin Lavender' plants needed a higher water content in the growing substrate than *Petunia*. This result could explain the higher biomass production and number of flowers of *Impatiens* with mulching compared to *Petunia* in the current experiment. Similar results were obtained by Ram et al. [2003] with geranium (*Pelargonium graveolens* L'Hér.) plants, where mulching promoted a greater vegetative biomass production due to higher soil moisture and better supply of nutrients. In another study, the flower dry weight of *Matricaria recutita* L. was decreased by drought stress in soil [Baghalian et al. 2011]. Blom et al. [2008] reported that *Impatiens* plants total root length decreased with increasing moisture deficit in substrate. In the present study, the root dry weight of *Impatiens* was positively correlated with the flower diameter. This result shows that flowering of *Impatiens* depended on root growth parameters, which could be improved by higher soil moisture.

Mulches effect on soil properties. An explanation for the greater soil EC values in the plots with fresh grass and pine bark mulches probably resulted from the increasing availability of ions in the soil. This is in agreement with the observations by Medina et al. [2009], where it was found that the EC value of growing substrates increased due to their high concentrations of ions (NO_3-N, P, K, Na). In the present study, strong positive correlation between the soil K content and EC was observed. Fresh grass and pine bark had higher content of K and Mg compared to peat. The increase of soil EC from 0.59 to 0.74 dS m^{-1} with addition of corn (*Zea mays* L.) residues to the soil was found by Alijani et al. [2012]. This suggests that fresh grass and pine bark mulch increased soil nutrient ions' concentration through biological mineralization of nutrients [Tiquia et al. 2002].

The greater increase in soil pH in fresh grass and pine bark treatments probably resulted from the higher amounts of K and Mg in these mulching materials and higher amount of Ca in case of pine bark. As a result of biological mineralization of nutrients, higher amount of cations of K, Ca and Mg may increase the base saturation of the soil and result in increasing soil pH [Shen and Shen 2001]. In the present study, strong positive correlations were obtained between the pH and EC and between the pH and K content. The lower pH content under the peat mulch compared to other mulches could be explained by the naturally low pH value of peat material. These results show that peat mulch is more suitable for plants preferring lower than neutral soil reaction. In addition to chemical properties, fresh grass and pine bark mulches also increased the soil moisture, as it was expected in a low rainfall period. It has been found before that mulching helps to decrease evaporation from soil surface [Olasantan 1999].

However, in the present experiment no increase in the soil moisture and EC in peat mulch treatment was found. An explanation for this might be that as the peat mulch absorbed rain water, it could not pass through the mulch to the soil. The Sphagnum peat materials are fibrous and, therefore, absorbed gas and humidity and also possessed a high water-holding capacity [McBrierty et al. 1996]. Dry soil has less electrical conductivity than moist soil, because water present in the pore spaces of the soil increases the movement of free ions in the soil and thus the electrical conductivity [Ekwue and Bartholomew 2011].

CONCLUSIONS

All studied mulches, namely fresh grass, pine bark and peat, are suitable for mulching *Petunia* × *atkinsiana*, *Impatiens walleriana* and *Tagetes patula* plants in short growing period in a temperate climate. Fresh grass and peat mulch increased plant diameter of *Impatiens* and plant height of *Petunia* and *Impatiens* 40 days after planting. Fresh grass is the best mulch for *Impatiens* plants, which grew larger. All investigated mulches enhanced diameter of *Tagetes* plants 40 days after planting. The number of *Impatiens* flowers was increased by all mulches, but in case of *Tagetes* by pine bark mulch. Fresh grass and pine bark mulches enhanced soil moisture, EC and pH in the second year.

Results showed that studied organic mulches increase plant flowering and growth through the improvement of water and nutrient ions' availability in the short growing season. As a result, the use of these mulches can help to decrease additional watering applications and fertilizing for annual bedding plants in urban landscapes, therefore help to preserve water resources. Use of fresh grass and pine bark as mulch provides an opportunity for utilization of these organic wastes. These mulches are possible to be used as an alternative or substitute for peat mulch, which can help to decrease using peat in horticulture.

ACKNOWLEDGEMENTS

Research was supported by Estonian Science Foundation Grant No. 6157 and target financed project No. 0172655s04.

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