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Evaluating the environmental performance of the growing media in a green wall system in a dry climate region

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Abstract

Application of green walls still has not attracted interest among the contractors and people, and this can be due to poor growing performance of the plants on these systems. This study investigated the effect of four growing media types (30% cocopeat + 65% perlite + 5% vermicompost, 30% soil + 65% perlite + 5% vermicompost, 30% mushroom compost + 65% perlite + 5% vermicompost and regular soil as the control) on the performance of three plant species (*Frankenia thymfolia*, *Vinca minor*, and *Potentilla* sp.) on green walls under arid climate of Mashhad city in Iran. In the control growing medium with no organic matter, Frankenia maintained the highest moisture and the lowest temperature compared to the other growing media types. The growing media did not affect the root and shoot fresh and dry weight and leaf relative water content of the Frankenia. *Vinca minor* in the cocopeat and mushroom compost produced the highest root fresh and dry weight; however, changing to the growing media types enriched with organic matter content did not affect the shoots fresh and dry weight of this plant type. The growing media containing organic matters compared to the control growing medium, improved relative water content of the Potentilla leaves. The growing media containing organic matters, especially mushroom compost, had positive effects on improving the growth performance of the green walls, through maintaining the moisture content of the media, and thus the relative water content of the leaves, which enhanced vitality of the plants.

Keywords*:* Growing medium; Vertical garden; Cover plant; Substrate; Moisture

1. Introduction

Urban green spaces play a key role in improving the ecological, environmental and even psychological health of the people. The trend of urbanization has reduced the vegetation cover and thus increased environmental issues such as pollutions and energy consumption (Banco-Mundidl, 2013). Development of the green spaces and even its distribution in neighborhoods, especially in urban centers, is considered as one of the major challenges of the contemporary metropolis as supposed to be commensurate with urban construction styles (Yazdan Dad *et al*., 2010). Green facades and green walls are one of the options that help the sustainability of urban spaces through optimum use of spaces and resources (Kazemi and Mohorko, 2017).

Various studies have shown how green infrastructure positively has affected on the ecosystem and environmental functions such as wind and temperature control (Caprotti and Romanowicz 2013), reduction of the effects of urban thermal islands (Cameron *et al*., 2014), carbon sequestration (Marchi *et al*., 2015), reduction of noise pollution (Romanova *et al.*, 2019), reduction of air pollution (Francesca *et al*., 2019), purification and recycle of sewage (Kew *et al*., 2014), improvement of urban aesthetics and psychological enhancement on people (Koch *et al*., 2019). An increase in the habitat for urban pollinators and small animals (Dover, 2015), and

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production of food in green walls are relatively novel ideas for designing food production systems in cities (Fisher, 2013). Despite the growth of the popularity of green wall systems in cities, these systems are still under development, and more knowledge is needed to improve some of their positive impacts.

Applying the principles of Xeriscaping is one of the main recommendations for water saving landscaping in the areas with water crisis (Kazemi and Safari, 2018). This dry landscaping method includes a number of principles such as planning and design, soil mulching, selection of suitable plant species, application of new irrigation methods, appropriate maintenance, and soil or plant bed amendments. The two principles of plant selection and soil or plant bed improvements appeared to be more important than the rest for arid and semi-arid development (Ellefson and Winger, 2004). Traditional methods of combining the plants and growing media should be equipped with new technologies to improve their performance and provide maximum benefits for these systems (Ghaffarian Hoseini *et al*., 2013). This need is more profound in green infrastructure design such as green roof and green wall systems. Water storage capacity in vertical green infrastructures especially in arid and semi-arid climates is very important (Kanechi *et al*.,2014, Kazemi and Mohorko, 2017). Lin and Lin (2011) recommended the use of burned sludge (a material with high porosity of 37% and water holding capacity of about 32%) as a substrate for green roofing. In this experiment, four bedding compositions of sand, charcoal, and burnt sludge we used of which only burnt sludge resulted in strong root systems. Kazemi and Mohourko (2017) also reviewed the types of growing media used in green roof conditions around the world. The results showed most of the research on growing media of green roofs have been conducted in temperate regions (in the C-Geiger climate classification of group C), and continental climates (group D), respectively; and the least research has been performed on dry climate conditions of the world. Different materials including natural materials such as sand, clay, rock, and mineral shells, and industrial materials such as shale, vermiculite, perlite, and rock wool are usually used in green roof substrates (Durhman *et al*., 2007; Dunnett and Kingsbury, 2008). Research on green wall substrates is limited. However, Pérez-Urrestarazua (2019) in a study on three different substrates (expanded clay, perlite, and pumice) tested in six living walls found that the three substrates were suitable for living walls and most of the differences observed were due to the lighting conditions. Among the three substrates assessed, pumice exhibited a slightly better performance in terms of green cover and biomass production. The point which is clear in most research on green infrastructures is that future research and guidelines in this area should consider climate conditions of the area in designing the crop environment, depth and specificity of the systems to enhance the plant performance. Also, landscape planning and strategy development in vertical green spaces should mitigate the drought and temperature stresses of the plants in arid climate zones with more serious water scarcity. Such aims can be highly achieved by reducing the temperature fluctuations of the growing media and by increasing the water holding capacity of the growing media (Kazemi and Mohoroko, 2017).

Proper understanding of the physical and chemical characteristics of the growing media, along with a deep understanding of native ecosystems, and relationships among the water, the growing medium, the plants, and the physiological environment, are necessary to maintain the stability of vertical green spaces under different climate zones (Williams *et al*., 2010). Water and plant relationships affect the photosynthesis of plants and their evapotranspiration and are important to maintain healthy plants in these systems. The chemical and physical properties of the growing medium affect such relationships. Soil water content, water penetration rate, density, pore volume and porosity, nutrient holding capacity, pH and electrical conductivity are some other properties of the growing media that affect plant performances (Young *et al*., 2015). It seems presence of organic matters is important in improving the plant growth. Some studies have shown that organic waste such as urban wastewater, sewage sludge, animal manure and livestock, paper, pruning waste and mushroom media and any other green waste after composting can be used as a substitute for peat in the growing media (Gayasinghe *et al*., 2010).

Peat has high exchange capacity and physical properties (Abad *et al*., 2001), but due to its environmental concerns and high prices, it has been less used recently. Thus, finding a suitable alternative to peat is essential (Samiyi *et al*., 2005) and materials like compost and vermicompost seem to be good substitutes.

Vermicompost, as an organic fertilizer produced through organic matter decomposition by earthworms, increases the accumulation of microorganisms in the soil. These microorganisms can produce plant growth regulating hormones such as auxin, gibberellin, cytokinin, ethylene and ascorbic acid, which affect the plant growth. Many studies have indicated that vermicompost has high porosity, good ventilation, good drainage, and high water holding capacity (Tomati *et al*., 1987).

The use of mushroom compost as a replacement for peat and cocopeat (Abad *et al*., 2001). Today, mushroom composts are the waste resulted from mushroom cultivation and includes various components such as wheat straw and stubble, livestock manure, bird manure, cottonseed hull. The mushroom compost is used as soil enhancer for horticultural crops including grapes. Mushroom compost contains high organic matter and high water retention capacity, but the use of fresh compost has limitations such as high salt, which should be used for salt-sensitive plants. In general, the mushroom compost when washed, compared to non-washed, showed better performance (Kubilay and Topcuoglu, 2007). In a pot experiment, washed mushroom compost was applied at different levels of 0, 15, 30 and 60 tons per hectare along with pepper pot soil and their results showed that up to 30 tons per hectare of this compost increased the growth indices, yield and content of nutrients, but beyond this amount the plants were wilted due to high salinity (Sagar *et al*., 2009). Due to its higher porosity compared to conventional soils, cocopeat causes better root growth and development, and results in lower shoot to root ratio and improved rooting system enhances the drought tolerance (Treder, 2008).

Selection of plants for green roofs and green walls is also quite important. In most cases, species of Sedums that are not invasive and can grow well in shallow and dry soils would be used (ASTM International, 2014). While increasing the green per capita is important, selection of the suitable plant types especially those that stay green during the four seasons of the year are highly required. Plants also should require minimum maintenance but show maximum efficiency in resource consumption. Due to vertical growth of the plants and difficult access to them at heights, priority is given to plants that require least pruning. In the process of plant selection, the radiation requirement should also be considered. Finally given the depth of the growing medium in the green walls, plants with shallow rooting, adaptable, permanent type and evergreen are desirable (Onmura, 2001). Cover plants are fast-growing and quickly cover the surface of the soil and due to their low height, provide a beautiful appearance. These plants also usually do not require much water, and have low maintenance demand and prevent growth of the weeds because of their rapid canopy expansion. (Bowker and Edinger, 1989). Research works are available on some of the ground cover plant species suitability and drought tolerance. For example, in a study by Elhami (2016) the resistance to drought stress of some ground cover plants under climate conditions of Mashhad was investigated. *Vinca minor*, *Potentila* sp. and *Frankenia thymifolia* performed the best under drought stress on flat green spaces. Also, Vahdati *et al*. (2017) in a green roof research in Mashhad, investigated chilling (cold season) and drought (warm season) adaptability and resistance of nine plant species namely *Agropyron cristatum*, *Festuca aurundinacea*, *Festuca ovina*, *Potentila sp.*, *Frankenia thymifolia*, *Vinca minor*, *Sedum acre*, *Sedum spurinum*, *Carpobrotus edulis*. To further address the research gap on green wall system adaptability in arid and semi-arid climate conditions of Mashhad the current research investigated the performance of *Frankenia thymfolia*, *Potentilla* sp., and *Vinca minor*. Planted in different growing media in outdoor green wall systems in this city.

2. Materials and Methods

This experiment was carried out in the experimental fields of the Department of Horticulture and Landscape at Ferdowsi University of Mashhad. Mashhad is the second biggest city in Iran and is located at the north east of the country (36° 18' 38.5164" N *and* 59° 35' 58.0452" E.) with semi-arid climate, cold winters and hot dry summers. The average annual rainfall is about 255 mm, with very low rainfall events in springs and autumns. The average minimum and maximum mean annual temperatures are $4^{\circ c}$ and $22^{\circ c}$, respectively (National Centers for Climatology, 2019).

Plants were cultivated in early June 2018 and the experiment continued until the end of May 2019. To conduct this research, vertical plant panels were located in a location with appropriate distance from the shadow and facing toward the south. The vertical plant system used in this experiment was constructed according to the proposed vertical box packing system registered under invention number of 87011 in Iran. Each green wall was a 3 × 3 m^2 structure which was considered as one replication in the experiment (Figure 1). In each wall, four panels were constructed and each panel contained a growing media types. On each wall, 12 plots (experimental units) with a 100 cm length and 36 cm width were available and in each plot 18 plants from each species were planted. Three study plant species included *Frankenia thymfolia*, *Potentilla* sp., and *Vinca minor*. The selection of these plant species was based on the previous results and selection of the most resistant plant species in flat green space studies (Elhami, 2016), and green roof studies (Vahdati *et al*., 2017) in Mashhad climate conditions. The experiment was split plot based on randomized block design with three replications. The main factor was the growing medium in four levels and the second factor was plant species in three levels. The four growing media were analyzed in the laboratories of the department of soil science of Ferdowsi University of Mashhad (table 1).

Table 1. Physical characteristics of the growing media

Growing media	FC%	PWP%	PORO%	Bulk density(gr/cm3)
30% cocopeat + 65% perlite + 5% vermicompost	740.53	1.05	78.00	0.26
30% Leaf composts+ 65% Perlite + 5% Vermicompost	69.09	8.96	42.00	0.60
30% mushroom compost + 65% perlite + 5% vermicompost	113.00	4.59	56.00	0.29
Common soil as the control	38.00	4.74	8.00	0.75

* PORO: Porosity (%), Bulk density: Apparent specific weight of the soil (g/cm3), FC: Field Capacity (%), PWP: Permanent wilting point (%)

Table 2. Chemical properties of the growing media types

Growing media	N%	P%	K%	OC%	OM%	C/N	pH	EC	Mg(%)
30% cocopeat + 65% perlite + 5% vermicompost	0.321	0.056	0.40	6.56	11.31	20.44	6.87	1.32	0.73
30% leaf compost+ 65% perlite + 5% vermicompost	1.254	0.086	0.33	8.89	15.32	7.09	7.21	1.39	0.70
30% mushroom compost + 65% perlite + 5% vermicompost	0.700	0.092	0.17	10.92	18.83	15.06	7.16	2.83	1.37
Commonsoil as the control	0.125	0.003	0.01	2.62	4.52	20.96	8.02	1.22	0.26

*OC: organic carbon, EC: Electrical conductivity (dS.m-1), OM: Organic mater

Maintenance of the green walls were performed on a weekly basis and in each time the growth condition of the plants, the absence/presence of pests and diseases, and the performance of the irrigation system were monitored. The irrigation was performed using a drip irrigation system. The moisture contents of the growing media was determined by a moisture sensor model (USA, EXTECH MO750) at a 10 cm depth from the surface and at 12 noon on a weekly basis. The temperature of the growing medium was also measured weekly between 12 noon to 2 pm, by a Soil thermometer (TH 310). Measurement of the leaf relative water content (RWC) was based on Hussein *et al*. (2010) method using the following formula:

$$RWC = (Fw-Dw) / (Tw-Dw) \times 100$$

Where Fw is fresh weight, Dw is the dry weight and Tw is the fully swollen leaf weight.

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). The amount of chlorophyll a and chlorophyll b were measured at the end of the experiment by applying the method of Dere *et al*. (1998).

Statistical analyses were performed using JMP V.8 software. The means were compared using Tukey's test. Finally, the graphs were drawn using an Excel software package.

3. Results

The results of the analysis of variance of the measured traits are shown in Table 4.

3.1. Measured factors

3.1.1. Growing media moisture

The results of the analysis of variance indicated that the simple effects of the growing medium and the species at 1% probability level and the interaction between the species and the growing medium at the 5% probability level were significantly different (Table 3). Comparison of the means showed that for all the three plant species, the common soil as the growing medium had significantly the highest moisture content and the growing medium containing mushroom compost had the lowest moisture content (Figure 2).

Fig. 1. The structure of the three green wall systems in this experiment

Table 3. Analysis of the variance of the physiological and growth traits

Sources of Variation	df	GMM	GMT	RLWC	Chl a	Chl b	Total Chl	FRW	DRW	RL	FSW	DSW
Block	2	532.68	1.06	9.06	0.38	0.20	1.70	0.02	0.02	2.62	1.02	0.25
Growing Medium	3	3565.5**	40.5**	328.5**	3.9**	4.45*	7.79	8.03**	0.41**	37.07**	17.01**	3.53*
Main factor error	6	127.32	0.44	28.2	0.6	0.69	3.07	0.09	0.008	1.35	0.70	0.39
Species	2	1914.4**	12.9**	51.6	3.50**	5.76*	10.6*	20.99**	1.03**	37.5**	1254.17**	321.28**
Species × Growing medium	6	313.3*	10.05**	117.2*	0.97	1.12	1.26	3.84**	0.24**	1.27	4.66**	1.05*
Total error	16	80.29	0.83	36.8	0.79	1.07	1.86	0.39	0.04	0.94	0.97	0.32

** Significant at 1% level of probability, * Significant at 5% level of probability, ns: Non-significant, RLWC – relative leaf water content, df: degree of freedom,GMM: Growing Medium Moisture**,** GMT: Growing Medium Temperature, Chl: Chlorophyll, FRW: fresh root weight, DRW: dry root weight; RL: root length, FSW: fresh shoot weight; DSW: Dry shoot weight

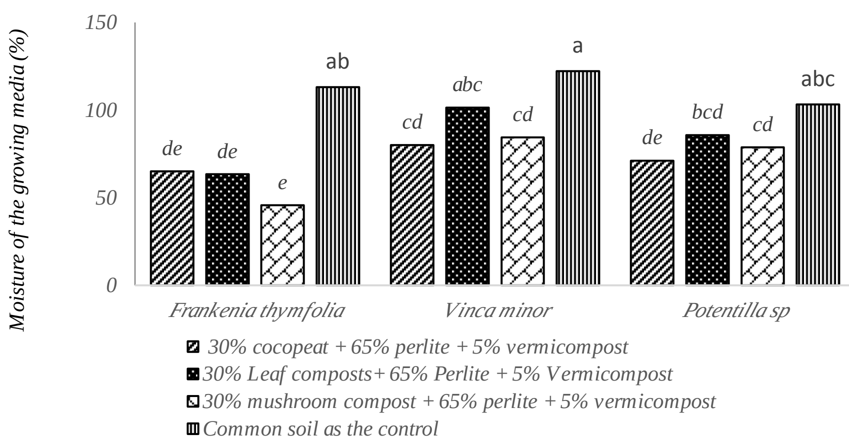


Fig. 2. The moisture content of the growing media (%) across different plant species and growing media types

3.1.2. Temperature of the growing media

According to the analysis of variance in relation to the growing media temperature, the simple and interactive effects of the species and growing media at the 1% probability level were significantly different. As shown in Figure 3, the maximum temperature in the growing media was monitored in *Frankenia thymfolia* and the *Vinca minor* in the mushroom compost medium and the lowest temperature was recorded in the *Potentilla* sp. in the soil as the control.

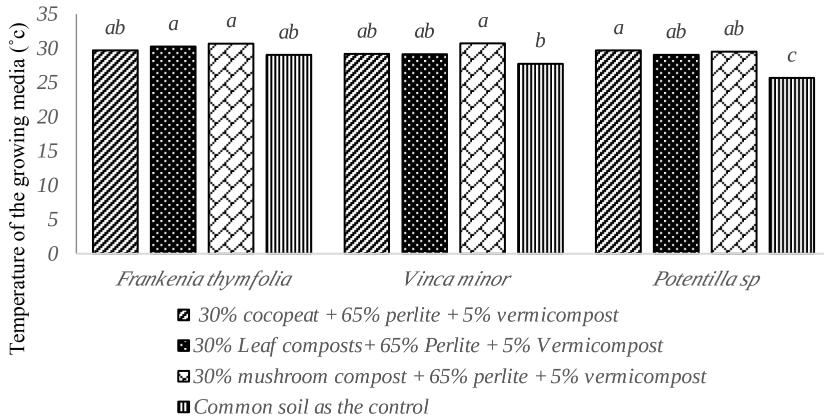


Fig. 3. Temperature differences of the growing media across different plant species and growing media types

Leaf relative water content: Simple effect of the growing media at 1% probability level and interaction between the species and the growing media were significant at 5% probability level. The highest relative water content of the leaf was observed (Figure 4) in the *Vinca minor* species in the cocopeat growing medium, but the two species of *Vinca minor* and *Francenia thymifolia* showed the lowest relative leaf water content in the soil .In Frankenia, the soil as the growing medium and the growing medium containing mushroom compost had the lowest relative water content compared to the other growing media types. However, the leaf water content of the plants were not significantly affected under the influence of the water content of the growing media.

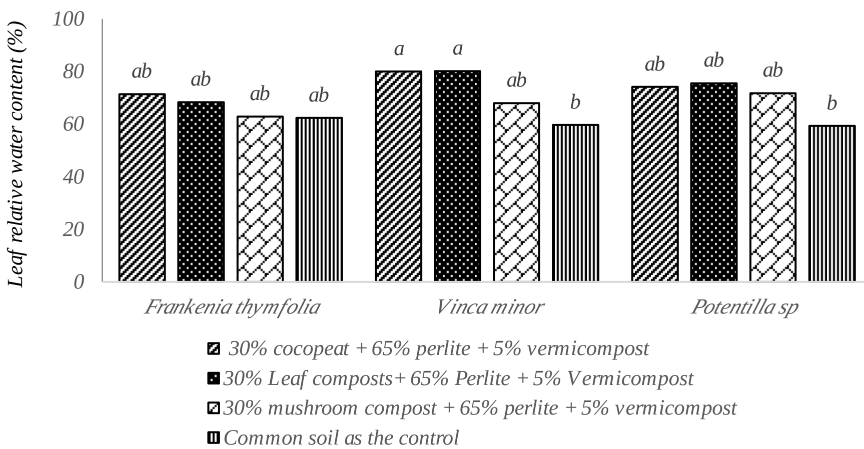


Fig. 4. Leaf relative water content (%) across different plant species and growing Media types

3.1.3. Chlorophyll content

The results of the analysis of variance of the chlorophyll a and chlorophyll b contents showed that the simple effect of the species and the substrate for these factors were significant at 5% probability level. However, for the total chlorophyll, only plant species showed significant differences. Among the growing media types, the soil as the control treatment showed a statistically significant association with the lowest chlorophyll content in the plants (Figure 5, 6).

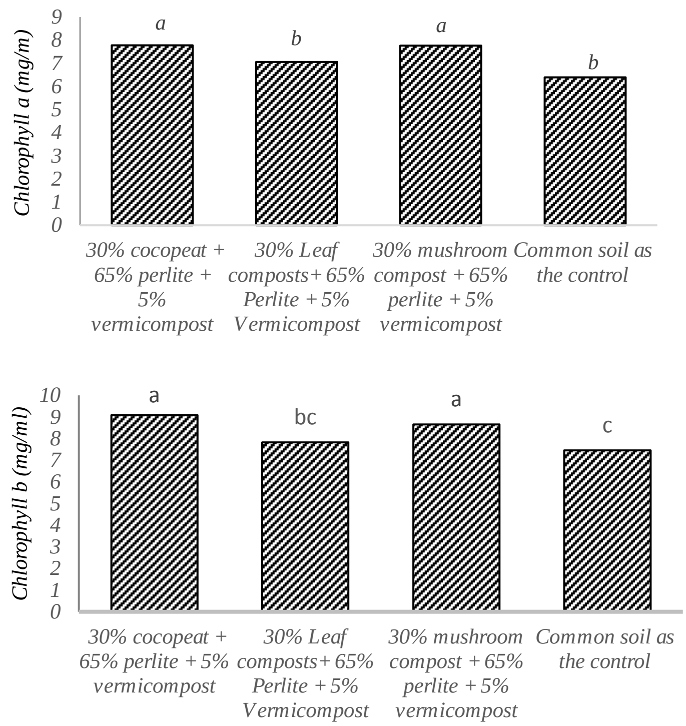


Fig. 5. Comparison of the chlorophyll a and b contents across the four growing media types

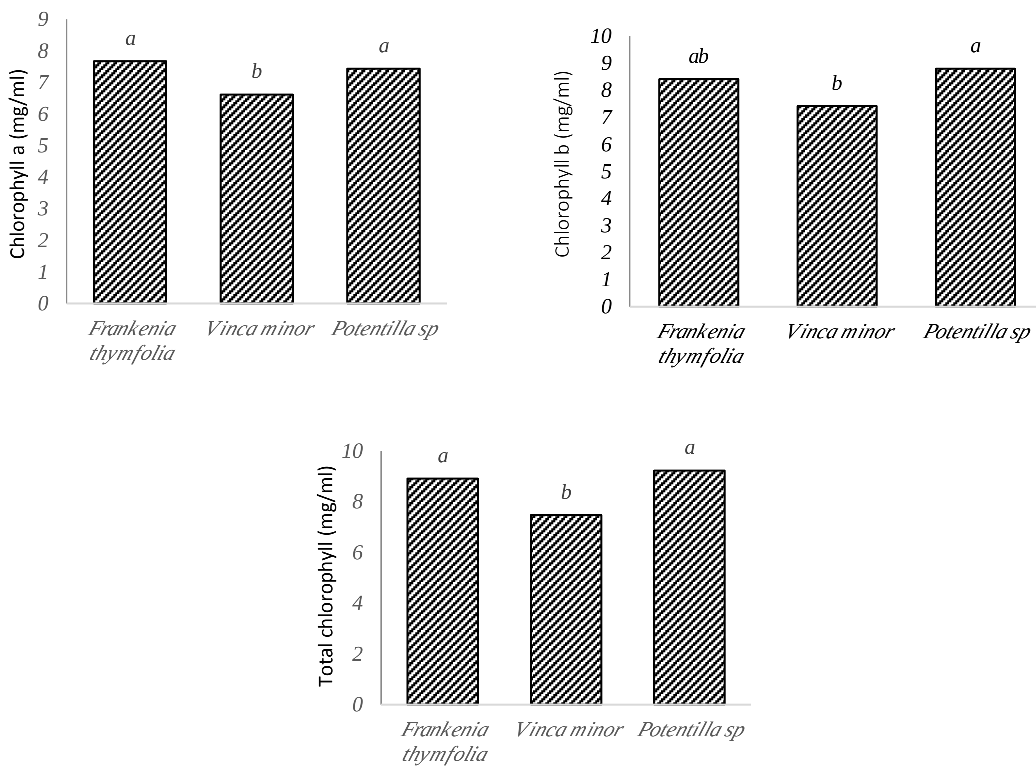
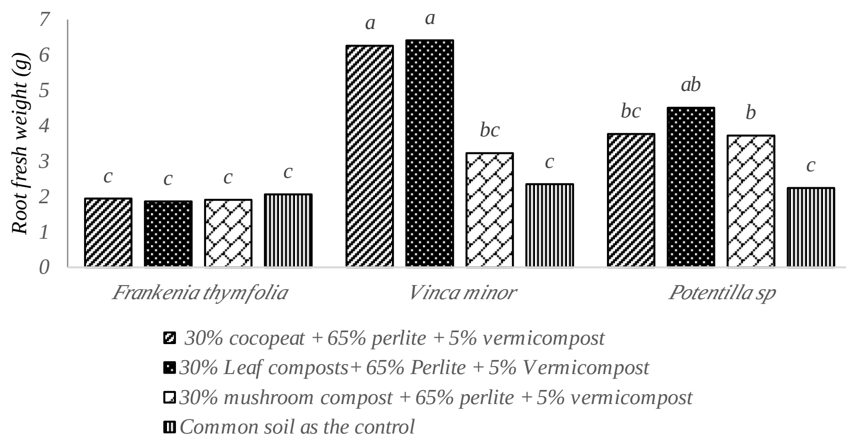


Fig. 6. Comparison of the chlorophyll contents across the studied plant species

3.1.4. Root fresh and dry weight

As the analysis of variance showed, there was a significant difference among the three species for the root fresh and dry weight ($p \leq 0.01$). Frankenia showed the highest rank for these traits in all the growing media types. In addition, across all the plant species and growing media types, Frankenia showed the lowest roots fresh and dry weight. The highest root fresh and dry weight was also found *Vinca minor* in both compost and cocopeat growing media types (Figure 7).

a



b

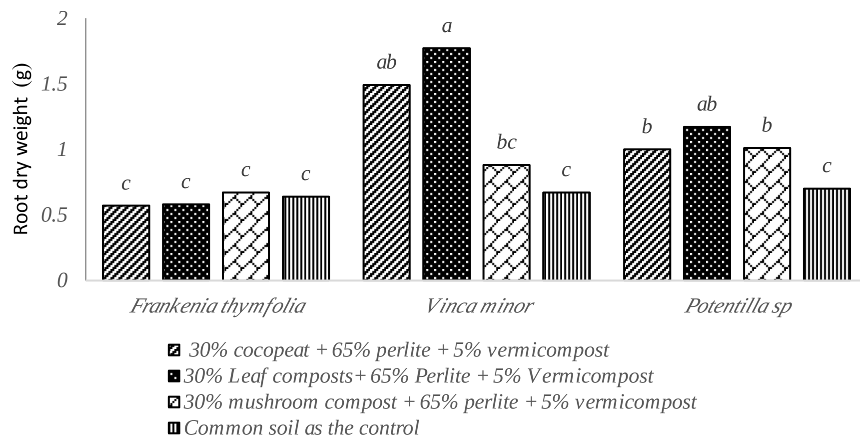


Fig. 7. The root fresh weight (a) and dry weight (b) across the plant species and growing media types

3.1.5. Shoot fresh and dry weight

As the analysis of variance showed, there were significant differences between the fresh and dry weight of the shoot parts among the plant species ($p \leq 0.01$). Frankenia showed the highest shoot fresh and dry weight among all the growing media types and plant species, but the lowest shoot fresh and dry weight was found in *Vinca minor* in the control soil (Figure 8).

3.1.6. Root length

For the root length, simple effect of the plant species and growing media showed significant differences (Table 3). As shown in Figure 9, the lowest root length was observed in the control growing medium (soil) and this factor was not statistically different in the other three growing media types. Disregarding the growing media type, Frankenia had the lowest root length compared to other plant types.

a

b

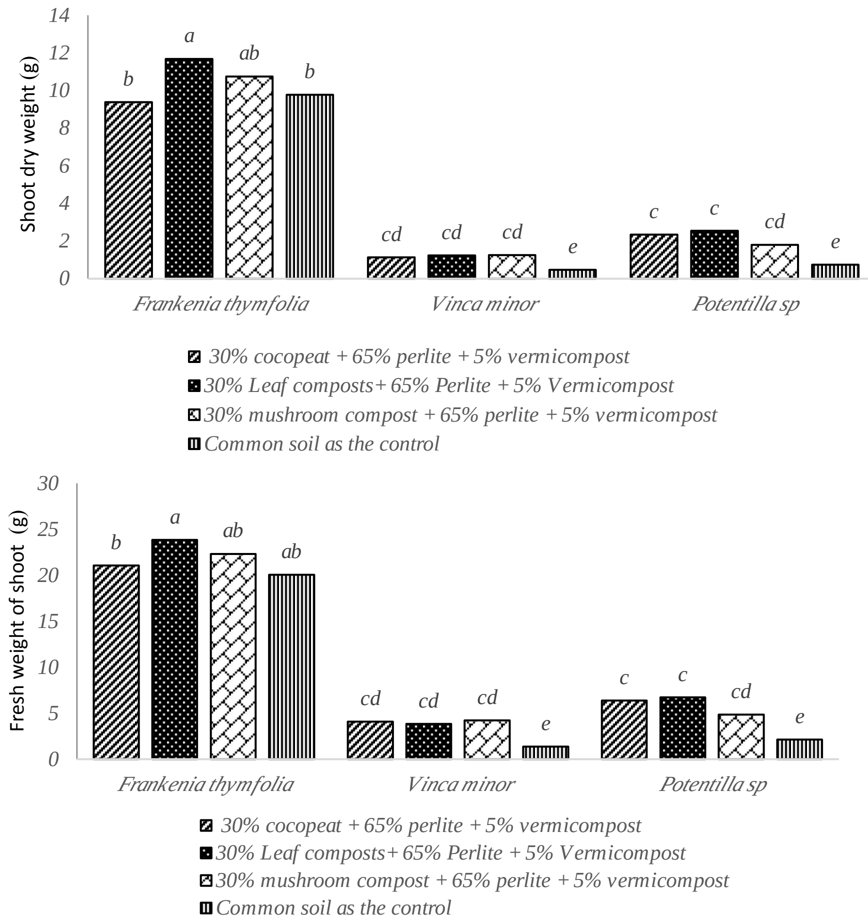
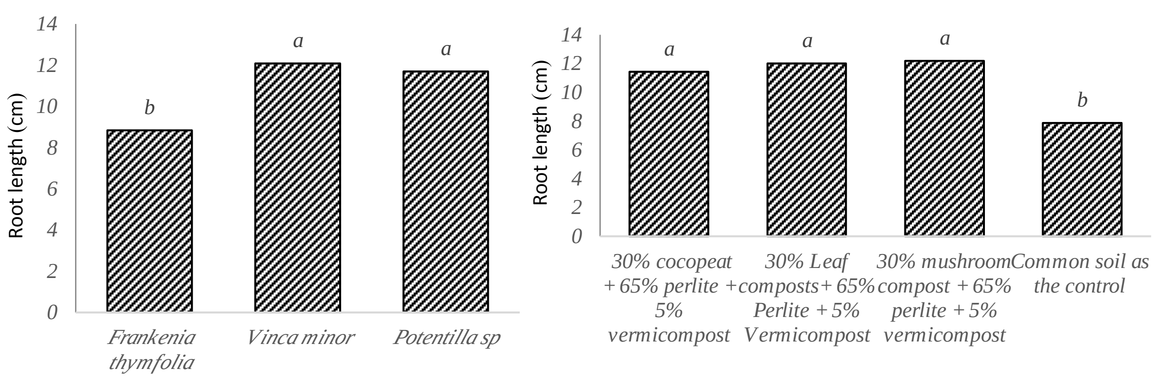


Fig. 8. Comparison of the shoot fresh weight (a) and dry weight (b) across various species in different growing media types



a b

Fig. 9. Comparison of the mean of the root length for, a. plant species, and b. growing media types

4. Discussion

Green wall technology is progressing, and every day new ideas are being implemented by designers. However, an important obstacle for this progress is sustainability, and this is not provided at least without providing a suitable growing medium for the plants in these systems. Soil is the most common growing medium and its temperature is an important factor affecting the plant growth. Temperature variations through different mechanisms affect the plant growth.

Reduction of the soil temperature by decreasing the root penetration (Lambers *et al*., 1998), increasing water viscosity and decreasing the speed of water movement in the soil (Kazluvsky and Palardy, 1997), can affect the absorption of water by the plants. The excessive increase of soil temperature can decrease the ability of the roots to absorb water (Nainanayak *et al*., 2008). Soil temperature not only reduces plant water absorption but also affects the absorption of important nutrients such as nitrogen (Dang *et al*., 2010). Reducing the absorption of water and nutrients can reduce the chlorophyll content, reduce stomata conductance, increase the resistance of cytoplasm (Afaloo *et al*., 2006) and reduce the net photosynthesis (Scwarz *et al*., 1997). In addition to direct effect on the electrical conductivity, soil temperature also indirectly affects this factor by influencing some physical, chemical and biological properties of the soil (Gavito *et al*., 2001). Soil moisture is one of the most important soil characteristics that can greatly control the soil temperature and modifies the soil conditions for plant growth. Therefore, application of different irrigation strategies due to changes in the spatial distribution of the moisture is a key factor on how temperature changes within the root zone of the plants (Dry *et al*., 2000).

In this study, temperature of the control soil compared to that in the other growing media was lower across all the plant species. It seems that cooler temperature in the control soil has decreased water absorption by the roots so more water remained in the control soil compared to the other growing media types. It should also be considered that higher moisture in the soil reduced the soil temperature as well and due to lower plant growth in the control soil, water consumption by the plants was also lower, and therefore, higher amount of moisture was remained in the soil. This finding contradicts with Butler and Orians (2011) report about the direct relationship between the plant growth (shoot fresh and dry weight) and low temperature of the growing medium. Usually, plants with higher growth rates increase soil temperature. This could be due to the presence of more organic matter in their growing media, which may have been due to the activity of the soil microorganisms through decomposition of the organic matters. In this study, plants growth in the growing media containing organic matters showed higher water absorption thus less water remained in the soil, and it may be argued that this is another reason for increasing the soil temperature. Rowe *et al*. (2012) found more water content in the growing medium by increasing the coverage and survival of the plant species which also reduced the temperature of the growing medium. They concluded that although wet soils have higher heat transfer coefficients than dry soils, when temperatures are closer to ambient, the soil moisture can allow the plant species to grow and expand their canopy. According to this study results, for both *Vinca minor* and *Potentilla* sp. although the moisture content of the control soil was higher and it's temperature was lower, due to its difference with the temperature of the surrounding environment the plants growth was lower.

The vertical growth habit of the plant species increases the amount of radiation received on the medium surface and the growing medium temperature will rise and the plant growth will decrease. In this experiment, *Vinca minor* plants with vertical growth habit, compared to the other two species types, increased the radiation emit on the soil and thus resulted in highest medium temperature which in turn was associated with those plants with the lowest growth. However, Frankenia, due to its higher water usage, had a lower moisture content in all the growing media types compared to the other two plants species, and subsequently faced higher temperatures in its growing media.

Nitrogen is one of the essential factors in leaf area expansion, and is responsible for plant rapid growth (Soltani, 2009). Nitrogen availability increases the growth and leaf area of the plants, and thus increases the absorption of light, which results in higher dry matter and plant yield (Van Delden, 2001). On the other hand, the amount of nitrogen mineralization is influenced by biological factors, the type and amount of vegetation and decomposing organisms and abiotic factors such as soil texture, moisture and organic nitrogen content of the soil (Rajaee and Reissi, 2010). However, in this experiment, although the soil moisture content was higher in the control soil, the growth rate of all the species in this growing medium was lower than that in the other growing media which could be due to lack of sufficient organic and inorganic materials in the soil. This hypothesis may be proved by the lowest amount of N, P and K, organic carbon and organic matter in this type of the growing medium compared to the others as shown in Table 1. Akramiynezhad *et al*. (2015) stated that plants had a higher chlorophyll index compared to the control plants when were grown in organic and chemical fertilizer treatments. Mushroom compost residue is a source of organic matters and nitrogen, and, over time, with provision of nitrification conditions, nitrogen is released into the form of minerals and can be absorbed by the plants (Medina *et al*. 2012). In this study, the growing media containing higher organic matters increased the greeness index and these results are consistent with the findings of Fakharia (2008), which reported that when nitrogen and calcium elements applied along with organic compounds such as mushroom compost, then the greenness index increased. According to Azarma *et al*. (2017), the relatively high or low temperature of the root environment affects the magnesium absorption by the plants, but this effect can depend on the type and stage of the plant development. Since this element is the main component of the chlorophyll, it can also affect the amount of plant chlorophyll content. Therefore, keeping the temperature of the root environment close to the air temperature is the most suitable condition for producing higher yields and better air quality for the plants.

Root growth is controlled by environmental and genetic factors. The resistance of some plants against drought is dependent upon the frequency of the branching of their root system to absorb the required water from a larger mass of the soil (Rad *et al*., 2008). In this study, plants in the growing media containing organic matters, had longer root systems than those grown in the control soil medium. This is consistent with Rad *et al* (2008), which in their studies about the growing media containing vermicompost a positive effect on the improvement of fresh and dry weight of both shoot and root, and the leaf relative water content and chlorophyll content, and ultimately the plant's vitality were monitored.

Root penetration depth is further restricted in soil under low temperature conditions than at higher temperatures (Alvarez and Körner, 2007). It has been reported that the temperature of the root zone is one of the major limiting factors for growth and respiration of the roots (Gavito *et al*., 2001). It can be argued that one of the factors reducing root length in the control medium soil than the other three growing media in this experiment was lower temperature of this growing medium. Root function at low temperatures is affected by changes in water viscosity, root pressure, hydraulic conductivity, metabolic activity, production and upward movement of plant hormones and the ability of roots to absorb nutrients and water (Alfocea *et al*., 2010). Among all the root tasks, the absorption of nutrients is more than other tasks under the influence of the temperature of the root environment (Zhao *et al*., 1998). Shibani Rad *et al*. (2015) stated that photosynthesis would be reduced by decreasing the temperature, and hence, the development of the shoots would be prevented.

When the root temperature for a long time is higher than the air temperature, it would impact root activity and growth of the plants (Ronaghi and Moftoon, 2003). The result of this study is consistent with Ronaghi and Moftoon (2003) who found that in organic growing media with higher and near ambient temperature in the summer (average summer temperature of 30 to $40^{\circ C}$), plants performed better than that in the control soil. The temperature of the compost medium with mushroom and the control soil medium, which was close to the temperature of the surrounding environment, had a significant effect on shoot dry weight. Akramiynezhad *et al*. (2015) in a study on *Satureja hortensis* reported that livestock and organic compounds increased the relative water content of the leaves in the plants. In this study, plants in organic growing media had a higher leaf relative water content than that in the control soil medium. The reduction of leaf relative water content due to stress, has direct relation with the soil moisture content. In this experiment, although the soil medium had a higher moisture content, the relative water content of the leaves of *Vinca minor*, and *Potentilla sp*. was lower, which indicated that the root was not able to adequately absorb the water. Williams *et al*. (2010) showed that there is a direct relationship between the leaf water content and resistance to heat stress conditions in summer. Investigating the relative water content of the leaves in tested plants showed that Frankenia had the highest and *Potentilla sp*. grown on the green wall had the lowest resistance to hot summer conditions of Mashhad. The growing media with high water holding capacity, high porosity and a good drainage conditions can provide optimum growth and development of the root and aerial parts of the plants (Barrett *et al*., 2016). Further, the presence of sufficient nutrition in organic growing media leads to increasing the life span, the leaf areas and the photosynthetic surface of the plants and, finally increases the plant biomass (Soumare, 2003).

5. Conclusion

The growing media containing organic matters, especially the mushroom compost, can be used to improve the plant performance of the green walls. Increasing the root length and the ability to absorb the moisture from the growing medium and the presence of moisture in the plant organs increases the relative water content of the leaves and the plant's vitality. Improving the absorption of nutrients by the plants in these growing media, will result in better growth of the plants and proper physiological functioning of the plants compared with their performance in the soil medium. Similar to the results of the previous studies on Frankenia species in common green spaces (Elhami, 2016), and also green roof systems (Vahdati et al., 2017), using this species in the green wall cultivations is also recommended due to its high compatibility with Mashhad weather conditions in the summer seasons.

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