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PERFORMANCE ANALYSIS OF DIFFERENT GEOTEXTILE MATERIALS IN EXTENSIVE ROOF GARDEN DESIGNS

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Highlights

- Light synthetic filtration materials, the weight per unit roof area can be reduced.
- Different filtration materials featured in the study work positively in extensive roof arrangements.
- Polypropylene fabric has the lowest water holding capacity.
- The most successful material in terms of temperature, among the other filtration materials, is raw cotton fabric.
- Polypropylene fabric is recommended as a filtration material in extensive roof garden designs.

Abstract. Roof garden arrangements, which have emerged in recent years based on environmentally friendly approaches, not only increase urban aesthetics but are also a design approach that contributes to the solution of problems caused by climate change. In this study, the filtration performance of different geotextile materials was investigated based on the extensive roof garden model. The studies related to the research were carried out as an open field pot experiment in Ege University Bayindir Vocational School. *Crassula ovata* from succulent group plants was used as plant material. 3 filtration materials were tested as filter layers, namely glass fibre, raw cotton, and polypropylene fabric. Various statistical analyses were applied to determine the effectiveness of the filtration materials in extensive roof garden applications. According to statistical significance levels it can be said that the use of polypropylene fabric as filtration material would be more advantageous compared to alternative geotextile materials.

Keywords: glass fibre, filter material, landscape management, raw cotton fabric, polypropylene fabric, green roof.

Introduction

In the contemporary world, unplanned urbanization in parallel with population density and the increasing number of buildings have led to a decrease in urban green areas (Aras, 2019). The extensive time people spend in multistorey residences, especially in cities with dense housing, has increased the longing for green even more. It has been observed that the use of potted ornamental plants indoors has increased in the last years aiming to overcome this longing, but people's need for open green areas has not been sufficiently met. Thus, roof gardens, which are an innovative approach in terms of their convenient accessibility enabling citizens to participate in the limited recreational activities besides their contribution to urban aesthetics and ecology, have attracted significant attention. Roof gardens increase the economic value of the buildings they are located in, thus making them more preferable (Erkul & Sönmez, 2014). Especially, shopping malls, workplaces, hotels, hospitals, multi-storey car parks and some residential buildings have a flat or low-slope roof system, which provide space for the application of these gardens (Koç & Güneş, 1998a). Roof garden is a design approach that not only increases the aesthetics of the city, but also contributes to the solution of problems caused by climate change, such as high temperatures, heavy rain, floods and air pollution (Dunnett & Kingsbury, 2008). The creation of roof gardens on building roofs provides protection against ultraviolet radiation, and the planting also contributes to the urban ecology (Johnston & Newton, 1993; Pehlevan et al., 2010). Climate conditions, precipitation, extreme temperatures, and the absence of an irrigation

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system are the limiting factors during the selection process of the plant species suitable for roof garden designs. Thus, the use of native plant species is preferred in roof garden arrangements because of their adaptation capability to local conditions (Oberndorfer et al., 2007). Roof gardens are divided into 3 groups, extensive (sparse), intensive (dense) and semi-intensive, considering the depth of the plant carrier layer, plant species, planted surface area and vertical loads (Lanham, 2007; Calheiros & Stefanakis, 2021). In intensive roof gardens, although the design varies according to the topography, it is possible to use a wide variety of plant species from grasses and shrubs to trees, as the category is generally supported by a 25 cm higher layer thickness. The garden maintenance needs are the same as a conventional garden in terms of fertilization, irrigation, and plant protection. Compared to extensive roof gardens, their implementation and maintenance costs are higher. On the other hand, the plant species often preferred in extensive roof gardens are herbs, aromatic plants, mosses, and succulents placed on an 8–15 cm layer thickness. They require low maintenance as they have low irrigation input. They are generally not accessible by humans. Compared to other categories, they are significantly more profitable in terms of application and maintenance costs. It is supported by a 15–25 cm layer thickness and features a range of plant groups, from bushes and grasses to small plants. They can have several functions as garden areas and be accessible to people (Calheiros & Stefanakis, 2021).

The arrangements that cover the roofs, named eco roofs (Sailor et al., 2008), living roofs (Voyde et al., 2010), vegetated roofs (Ekşi, 2014), green roofs (Yücel, 2009), ecological roofs (Aras, 2019), and roof garden (Ekşi, 2012), are formed with different layers, adhering to certain principles. Accordingly, the roof cover consists of varying layers, including the plant carrier layer where the plants are planted, the filter layer, the drainage layer, the protection layer, the water and heat insulation layer, and the structural layer (Aslanboğa, 1988; Koç & Güneş, 1998a).

The filter layer, which is the subject of this research, may consist of granular material, flat plate, or non-woven fabrics. Filter layers laid on the drainage layer may consist of nonwoven materials of 0.7–2.5 mm thickness, such as polyamide (PA), polyacrylonitrile (PAN), polyester (PET), polyethylene (PE) and propylene (PP), glass fibres or fibres from several materials such as rock wool (Pehlevan et al., 2010; Erdoğan & Kemaloğlu, 1991; Küçükerbaş, 1991; Cunningham, 2001). Geotextile materials are generally used for the filter layer (Cascone, 2019). The main function expected from this layer is to prevent the passage of fine soil particles from the plant carrier layer to the drainage layer and to ensure the drainage of excess water. The drained excess water is removed from the plant carrier layer with the drainage layer located just below the filter layer (Seçkin & Seçkin, 2016). The materials preferred in the filter layer should be porous, long-lasting, not cause harmful reactions to the plant, not decompose easily, and have a light structure (Aslanboğa, 1988; Kolb & Schwarz, 1988; Koç & Güneş, 1998b).

When roof gardens are evaluated within the scope of the existing literature, it can be observed that extensive roof garden applications are preferred due to the low need for irrigation and maintenance, as well as their recreational use (Akpınar Külekçi, 2017). Accordingly, this study has preferred to investigate the design of an extensive roof garden that features a single species with a succulent structure that will not grow extensively tall, is drought resistant, and does not need rich nutrients.

This study examines the performance of filtration materials in terms of plant root development, the EC (Electrical conductivity) and pH value, drainage amount, in-pot temperature, plant height, number of leaves and solid matter permeability. The study was carried out in this direction and based on the extensive roof garden design, aiming to evaluate the performance of 3 different geotextile materials (glass fibre fabric, raw cotton fabric and polypropylene fabric) that were used as filter layers.

1. Materials and methods

1.1. Preparing of cultivation area, plant and filter materials

The research carried out at Ege University Bayındır Vocational School (38 12 ‘09.9 “ N, 27 ° 40’ 20.8 “E) started on 14.06.2021 and ended on 17.09.2021. The research area was organised as an open field pot experiment. The plant species that was used to achieve the research target was *Crassula ovata*, which belongs to the succulent (fleshy-leaved) plant family and is suitable for extensive roof garden designs. For this purpose, the chosen plant seedlings had reached a homogenous size, demonstrated healthy development, had 15 leaves on them, were 10 cm long and did not show branching. The reason why this plant was preferred in the study is primarily because it has different species, demonstrates better adaptation to climatic conditions, and the most used plant group in roof garden applications is succulents. In addition, this plant species' capability to reach the desired appearance in a short time by demonstrating rapid development was another quality that was taken into consideration.

The research area was planned in accordance to random blocks experimental design in 3 replicates. The factors examined in the study are given below.

Filtration materials:

– Glass fibre fabric (F1);
– Polypropylene fabric (F2);
– Raw cotton fabric (F3).

In roof gardens, the filter layer is a necessary layer between the drainage and the plant carrier layer (Koç & Güneş, 1998b; Özdemir & Altun, 2010; Seçkin & Seçkin, 2016). For this reason, a control group which did not feature any geotextile material for filtration purposes was not included in the creation of the trial area. In other words, the filtration materials group does not include a control group. The weight (g/m^2), some properties and the visuals of the geotextile materials featured in the study can be found in Figure 1.

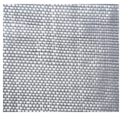
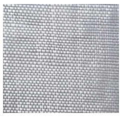
Geotextile materials	Glass fibre fabric 	Polypropylene fabric 	Raw cotton fabric 
g/m^2	195	95	124
Woven Type	Plain	Plain	Plain
Widht (cm)	80	130	150
Rigidity	High	High	Low
Moisture Barrier Properties	High	High	Low
Heat Resistance	Excellent	Moderate	Low
Cold Resistance	Excellent	Poor to fair	Moderate
Solvent Resistance	Excellent	Good	Low

Figure 1. The weight, some properties and visuals of the geotextile materials featured used in the experiment

Transparent plastic pots with a diameter of 15 cm and a drainage outlet opening at the bottom were used as pots in the trial area. Drainage containers with a volume of 1.5 L, connected to the drainage outlet, were placed at the bottom of the pots so as not to allow evaporation losses.

100% cotton supreme knitted textile material was laid at the bottom of the pots to determine the permeability of the solid material before placing gravel layer inside the pots. Then, gravels were placed in all the pots at a height of 5 cm. Just above the gravel layer, 3 different types of geotextile materials, namely glass fibre fabric (F1), polypropylene fabric (F2) and raw cotton fabric (F3), were laid as filtration material. The plant growing media was prepared by mixing the perlite (0.24 g/cm^3) substrate with soil at a ratio of 1:3. This plant growing media, which was prepared as a mixture, was laid on the filter materials at a depth of 8 cm to form a plant carrier layer (Figure 2).

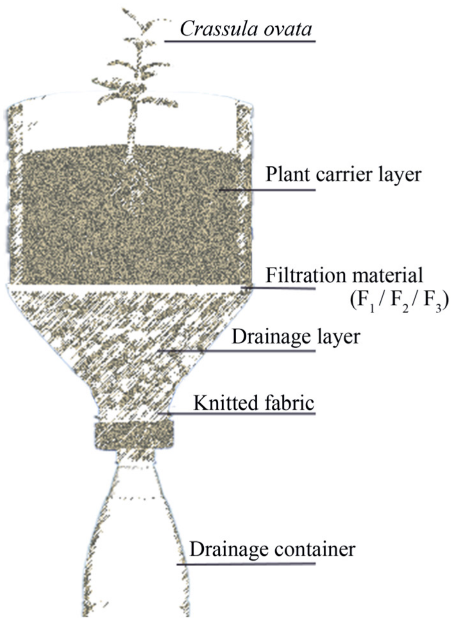


Figure 2. Cross-section of the pot used in the study

During the time covering the study period, no nutrient solution was added to the plant growing media since the plant material did not need fertilization. After the plant growing media was filled into the pots, one *Crassula ovata* plant was planted in each pot.

The irrigation process was initiated immediately after the plants were planted in their pots. The irrigation was arranged to take place regularly 2 days per week (400 ml/day) at 09:00 A.M. Thus, 800 ml of water was given to each plant per week. One day (almost 24 h) after the irrigation, in-pot temperature measurements were conducted through the plant growing media. For this purpose, considering the plant root depth, a depth of 5 cm from the surface was taken as a basis. A hand-held digital thermometer (TempLog Digital Thermometer) was used for temperature measurements (Figure 3). After the irrigations were completed, the drained water was collected in lidded drainage containers (Figure 4).

Figure 3. Digital soil thermometer

Figure 4. Drainage containers with lids

The drained water collected in the lidded drainage containers was measured by volume every week before getting removed from the system (Figure 5). After the drainage amounts were determined, the EC (Electrical conductivity) amount and pH value measurements were carried out in the drainage water once a week (Figure 6). An EC meter (WTW, Cond 330i conductivity meter set) was used for EC (Electrical conductivity) value measurements and a pH meter [WTW, pH 3210 (330i) pH meter set (portable)] was used for pH value measurements.

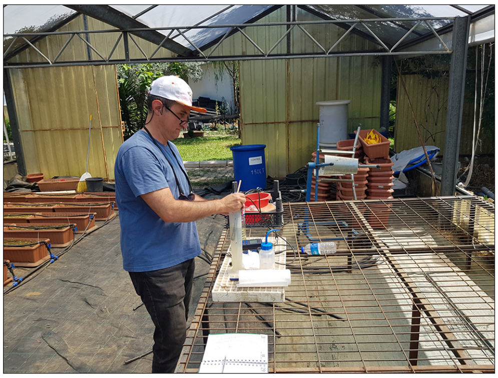


Figure 5. Measurement of drainage amounts

Figure 6. EC and pH measurements of drainage

To evaluate the effects of the 3 different geotextile materials used as alternative filtration materials on plant growth, plant height (cm) and leaf number (number) measurements were carried out once a week to observe the physical properties of plants. Furthermore, measurements regarding the amount of plant growing media (g) accumulated on the 100% cotton supreme knitted textile material laid under the gravel layer was carried out once at the end of the research to determine the solid matter permeability.

Various statistical analyses were applied to test the differences between the factors examined in this study regarding the varying filtration materials. The factors examined were EC (Electrical conductivity) value (μS/cm), pH value, drainage amount (ml), in-pot temperature (°C), plant height (cm), number of leaves (number) and solid matter permeability (g). Since the data can be variable, the Kolmogorov-Smirnov test was used to conduct a normal distribution test. While analysis of variance (one-way ANOVA) was applied to the variants demonstrating normal distribution, Kruskal-Wallis was applied to those who did not. The data of this study were analysed using the IBM SPSS Statistics (v21) software.

The aim of this research has been to determine, in the light of the obtained results, the material with the best filtration feature among the alternative geotextile materials that could be used in extensive roof garden designs.

This study has aimed to determine the filtration material that creates the most suitable conditions among the filtration materials taken into consideration, which could be used in extensive roof garden designs. For this purpose, a hypothesis has been developed regarding the filtration materials that can be used in extensive roof garden applications. This hypothesis is "Regarding extensive roof garden designs, each material taken into consideration in this study has shown differences in performance in terms of EC (Electrical conductivity) value (μS/cm), pH value, drainage amount (ml), in-pot temperature (°C), plant height (cm), number of leaves (number) and solid matter permeability (g)".

2. Findings

The research findings are given under 7 headings: EC (Electrical conductivity) value, pH value, drainage amount, in-pot temperature, plant height, number of leaves and solid matter permeability.

2.1. EC (Electrical conductivity) value

The EC (Electrical conductivity) measurements performed on the drainage samples obtained from the pot outlets featuring the research subjects were evaluated in terms of the filtration materials investigated, and the descriptive statistics results are given in Table 1. According to this, the lowest salinity (EC) value measured according to the filtration materials was determined in polypropylene fabric (F2) with 424.75 μS/cm, while raw cotton fabric (F3) was the material with the highest EC (Electrical conductivity) value, 508.71 μS/cm. Due to the normal distribution of the data, one-way ANOVA analysis was applied to examine the statistical difference between the filtration materials in terms of salinity (EC) values.

Table 1. The salinity (EC) values (μS/cm) of filtration materials

Filtration materials	Mean	Minimum	Maximum	Std. Deviation
F1	453.17	302.00	742.00	120.46384
F2	424.75	254.00	706.00	115.23709
F3	508.71	298.00	815.00	175.65789

According to the results of the analysis performed, there was a statistically significant difference of 5% in terms of salinity (EC) values between the filtration materials (Table 2).

Table 2. Analysis of variance of salinity (EC) values in the experiments with different filtration materials

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	286 232.111	2	143 116.056	7.595	.001*
Within Groups	5 370 470.219	285	18 843.755		
Total	5 656 702.330	287			

Note: *Significant at p = 0.05.

2.2. pH value

The descriptive statistics of the pH measurement values according to the filtration materials featured in the study are given in Table 3. In terms of the filtration materials used in the experiment, the lowest pH value was observed in the raw cotton fabric (F3). The highest values of pH measured in the drainage samples were detected in glass fibre fabric (F1) and polypropylene fabric (F2), which had very close values (9.45 and 9.51 respectively).

Table 3. pH values according to filtration materials

Filtration materials	Mean	Minimum	Maximum	Std. Deviation
F1	9.45	8.64	10.52	.52988
F2	9.51	8.81	10.69	.60909
F3	9.04	7.88	10.27	.60464

According to the results of one-way ANOVA analysis, a statistically significant difference was found between the filtration materials in terms of pH values at a 5% significance level (Table 4).

Table 4. Analysis of variance of pH values in the experiments with different filtration materials

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	11.020	2	5.510	16,362	.000*
Within Groups	95.973	285	.337		
Total	106.992	287			

Note: *Significant at p = 0.05.

2.3. Drainage amount

The amount of drainage measured from the pot drainage outlets according to the filtration materials featured in the study are presented in Table 5. The highest drainage amount measured according to these amounts was spotted in polypropylene fabric (F2) with an average of 217.3 ml. The lowest value regarding the drainage amounts was determined in raw cotton fabric (F3) with 131.42 ml. Therefore, after this evaluation, it has been determined that the highest drainage will be provided if polypropylene fabric (F2) is used as the filtration material.

Since the data did not present normal distribution, the Kruskal-Wallis test was applied to determine the difference in the measured drainage amounts in regard to the filtration materials.

Table 5. Measured drainage amounts according to filtration materials (ml)

Filtration materials	Mean	Minimum	Maximum	Std. Deviation
F1	206.42	130.00	338.00	54.18962
F2	217.63	108.00	350.00	63.28735
F3	131.42	90.00	213.00	32.78642

According to the test results obtained, there was a statistically significant difference between the filtration materials in terms of drainage amounts (Table 6).

Table 6. Kruskal-Wallis rank test results of the measured drainage amounts in the experiments with different filtration materials

Filtration materials	Mean Rank	Test Statistics	
F1	165.45	Chi-Square	91.415
F2	188.54	Asymp. Sig.	0.000*
F3	79.51		

Note: *Significant at p = 0.05.

2.4. In-pot temperature

The values of the air temperature measured during the period of this study ranged between min. 28.00 °C- max. 49.90 °C.

The average in-pot temperature values measured during the study of the filtration materials are given in Table 7. Accordingly, the lowest in-pot temperature value among the measurements was found in the raw cotton fabric (F3) with 33.48 °C. However, the average temperature values measured in glass fibre fabric (F1) and polypropylene fabric (F2) were found to be quite close to the values determined in raw cotton fabric (F3).

There was no statistically significant difference between the filtration materials in terms of temperature values (Table 8).

Table 7. Average temperature values measured by filtration materials (°C)

Filtration materials	Mean	Minimum	Maximum	Std. Deviation
F1	34.11	28.00	49.90	4.30671
F2	34.01	28.20	41.30	4.42879
F3	33.48	28.00	40.60	4.21983

Table 8. Kruskal-Wallis rank test results of the measured temperature values in the experiments with different filtration materials

Filtration materials	Mean Rank	Test Statistics	
F1	148.97	Chi-Square	1.824
F2	149.40	Asymp. Sig.	.402
F3	135.13		

2.5. Plant height

The average plant height values measured according to the filtration materials featured in this study are given in Table 9. According to these values, the highest value for plant height was obtained in polypropylene fabric (F2) with 14.04 cm. When glass fibre fabric (F1) was used as the filtration material, the average plant height was 12.15 cm, and 11.60 cm in raw cotton fabric (F3). According to these results, the lowest values of plant height in terms of filtration materials were determined in raw cotton fabric (F3).

Table 9. Average plant heights by filtration materials (cm)

Filtration materials	Mean	Minimum	Maximum	Std. Deviation
F1	12.15	10.00	10.00	1.46703
F2	14.04	10.00	10.00	2.67938
F3	11.60	10.00	14.70	1.36541

Since the data did not show normal distribution, Kruskal-Wallis test was applied to determine the difference in plant height values measured in regard to the filtration materials. The test results revealed that there was a statistically significant difference between the filtration materials in terms of plant height values (Table 10).

Table 10. Kruskal-Wallis rank test results of the plant height values in the experiments with different filtration materials

Filtration materials	Mean Rank	Test Statistics	
F1	148.87	Chi-Square	16.593
F2	166.45	Asymp. Sig.	.000*
F3	118.18		

Note: *Significant at p = 0.05.

2.6. Number of leaves

The number of leaves measured regarding the filtration materials featured in the study can be found in Table 11.

According to the results, the highest value was determined in glass fibre fabric (F1) with 30.29 leaves per plant. This was followed by polypropylene fabric (F2) with 29.96 leaves. The lowest value among the filtration materials regarding the number of leaves was found in the raw cotton fabric (F3) with 27.67 pieces. However, there was no statistically significant difference between the filtration materials in terms of leaf number values (Table 12).

Table 11. Average number of leaves by filtration materials (numbers)

Filtration materials	Mean	Minimum	Maximum	Std. Deviation
F1	30.29	15.00	47.00	10.79243
F2	29.96	15.00	48.00	10.42355
F3	27.67	15.00	46.00	9.73415

Table 12. Kruskal-Wallis rank test results of the leaf number values in the experiments with different filtration materials

Filtration materials	Mean Rank	Test Statistics	
F1	157.55	Chi-Square	3.562
F2	137.42	Asymp. Sig.	.168
F3	138.54		

2.7. Solid matter permeability

The amount of plant growing media accumulated on the 100% cotton supreme knitted textile material laid under the gravel layer in each group, was planned to be measured once at the end of the research period. However, in the light of the measurement results obtained at the end of the study period, it was determined that there was no quantitatively significant accumulation in none of the groups. For this reason, the measurement of the solid matter permeability of the filtration material could not be made. The obtained result reflected that the 3 filtration materials which were the subjects of the study, demonstrate the expected performance and work positively in extensive roof garden arrangements, removing the drainage in the plant carrier layer without causing any loss in the plant growing media.

3. Discussion

The data obtained from the study regarding the filtration materials examined in this research are summarized in Table 13 and evaluated on a scale of 1–3 to demonstrate

Table 13. Ordinal distribution of factors compared by filtration materials (1: best; 3: worst)

Filter materials	EC (Electrical conductivity)	pH	Drainage amount	Temperature	Plant Height	Leaf Number
F1	2	3	2	3	2	1
F2	1	2	1	2	1	2
F3	3	1	3	1	3	3
Statistically significant difference among groups	yes	yes	yes	no	yes	no

their superior properties in a more understandable way. Accordingly, among all the data obtained in terms of filtration materials, the best case was evaluated with 1 point and the worst case with 3 points.

The results obtained in terms of EC (Electrical conductivity) value, pH value, drainage amount, in-pot temperature, solid matter permeability, plant height and number of leaves were evaluated in the pots where the plant roots had developed and the filter layers subject to this research were located. Also, the data obtained during the study of the groups with differing filter materials was summarized and demonstrated in Table 13 to reflect the filter materials' superior properties.

A general evaluation of the differing values regarding the filtration materials featured in this study was made by considering those with statistically significant differences. According to this, while polypropylene fabric (F2) was the best option in terms of EC (Electrical conductivity) value, drainage amount and plant height growth, raw cotton fabric (F3) was determined to be the best option in terms of pH value (Table 13). Considering all the data obtained from the research and the statistical significance levels, it could be said that polypropylene fabric (F2) would be a more advantageous filtration material compared to the other textile materials. The results of the solid matter permeability showed that all 3 filtration materials work positively in extensive roof arrangements, removing the drainage in the plant carrier layer without causing any loss in the plant growing media (Cunningham, 2001).

According to the results obtained from the research, the lowest value for salinity (EC) was determined in polypropylene fabric (F2). Salinity is a worldwide problem that limits vegetative production in agriculture and has the potential to reduce the visual quality of ornamental plants (Veatch-Blohm et al., 2014; Akat Saraçoğlu et al., 2019). With the increase in the EC (Electrical conductivity) level, which expresses the salinity in the plant's root zone environment, water intake decreases, and nutrient imbalance occurs (Sonneveld, 2001).

Accordingly, plant growth, yield, and quality decrease in parallel to the increasing salt level (Salachna et al., 2017; Akın & Kahraman, 2018; Paraskevopoulou et al., 2020; Sun et al., 2020). In addition, high EC (Electrical conductivity) has a negative effect on nutrient uptake such as pH and the productivity of the root zone environment where the plant grows. For this reason, the material that provides the lowest EC (Electrical conductivity) level among filtration materials is important in terms of creating a positive environment for plant growth in roof gardens (Sönmez, 2013; Kader et al., 2022). Therefore, in accordance with the results obtained from the research, it is recommended to use polypropylene fabric (F2) in extensive roof garden arrangements, as it has the lowest salinity value among the filtration materials.

The results obtained from the research show that the lowest value according to the pH measurement values was obtained with the use of raw cotton fabric (F3). Like other qualities, the pH level of the plant's root zone in the roof garden can change. However, it is suggested that the pH should be between 7.0 and 9.0, a range that allows the nutrient absorption of the plants used in roof gardens, and this should be stabilised to ensure the plants' health (Ampim et al., 2010; Kader et al., 2022). When the limit is exceeded, nutrients cannot be absorbed by plants and nutrient deficiency symptoms start being observed; root development, yield and plant quality are adversely affected (Sönmez, 2013; Ding et al., 2019). It is believed that the creation of a healthy growing green tissue which is also aesthetically pleasing can be ensured if the raw cotton fabric (F3), which was a subject of this study, is preferred as the filtration material.

When the results obtained from the study of the drainage amount were examined, it was determined that the highest value was obtained from the polypropylene fabric (F2). It is known that the amount of drainage water should be kept at a minimum to reduce the negative effects of excessive drainage on the environment and the cost of fertilizer (Başar, 2000). The expected function of the filter layer is to prevent the deformations caused due to mechanical factors on the roof and to drain the rainwater from the upper layers to prevent the damaging of the plants' roots or to allow them to be stored with the help of a mechanism when the accumulation is high (Akpınar Külekçi, 2017; Daryaei, 2019). Water permeability gives important results about the performance of the filter layer (Cascone, 2019). The drainage capability of the filter layer at a high rate is a desirable condition for the plant roots to develop in a healthy environment. In this context, the fact that the highest amount of water was drained in the polypropylene fabric (F2), one of the filtration materials featured in the study, means that a healthy environment will be created in terms of plant roots in the plant carrier layer above the filter layer. In addition, it has been concluded that this material with a high drainage capacity can prevent the building from being damaged by preventing excessive water accumulation that would impose an extra load on the roof during heavy rains.

According to the results of the research, the highest value of plant height in terms of filtration materials was determined in polypropylene fabric (F2). Plant selection is very important in extensive roof garden designs as plants are often exposed to harsh environmental conditions. In the Mediterranean climate zone, which is characterised by dry summer periods, the conditions become more challenging due to the lack of additional irrigation in roof garden applications which fall into this category (Eksi & Rowe, 2019). Drought resistance is a structural feature of the succulent plant group, including *Crassula ovata*, which has been proven by previous academic research (Farrell et al., 2012). It has been determined that various factors affect the development of the different plant species used in extensive roof garden designs. It has been concluded that the effects of these factors on the growth parameters of the species preferred in roof gardens may differ. In this regard, in the research where the *Crassula ovata* plant was used, it was concluded that polypropylene fabric (F2) could be used as a filtration material in extensive roof garden designs.

Conclusions

The weight of the roof covering layers used in extensive roof gardens designed for those with low load-bearing capacity is of great importance. If the roof garden is planned with the incorporation of new types of materials, light synthetic filtration materials, based on extensive planting design principles, the weight per unit area can be reduced (Ekşi, 2006). In accordance to this, it is recommended to use polypropylene fabric, which is the lightest material among filtration materials, according to the results of the research. It has been demonstrated that the 3 different filtration materials featured in the study work positively in extensive roof arrangements, remove the water excess in the plant carrier layer without causing any loss in the plant growing media and prevent it from mixing with the drainage layer. Furthermore, it was concluded that the most successful material in terms of temperature, among the other filtration materials discussed in this study, was raw cotton fabric. In addition, it was confirmed that the material with the lowest water holding capacity among the filtration materials is polypropylene fabric. Polypropylene fabric, which is the most successful filtration material among the filtration materials examined in our research, is recommended as a filtration material in extensive roof garden designs. In addition, it is argued that the results obtained through the evaluation of the filtration materials analysed in the study and the discussion of their positive effect on the roof gardens, that provide solutions to urban environmental problems, will contribute to the literature.

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Author contributions

The manuscript was written through contributions of all authors.

Conflict of interest

The authors declare no conflict of interest.

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