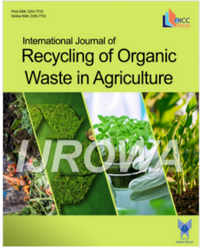

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Impact of compost and natural and synthetic water absorbents on soil hydraulic properties and vegetation indices in urban green spaces

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Original Research

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Abstract:

Purpose: In the current study, the effects of compost, natural, and synthetic superabsorbent amendments on soil water retention curve (WRC) were assessed by applying RETC software in a laboratory trial. Moreover, the effects of the mentioned materials on vegetation growth indices of four plants in three different soil textures of urban green space were evaluated.
Method: Using the randomized complete blocks-based split-plot design, the field experiment was conducted for a two-year period. The three soil textures were combined with 4 & 6 gr/kg hydrogel, as well as pumice, compost, manure, and perlite at 40 & 60 gr/kg levels.
Results: According to WRC findings, there was more efficiency associated with hydrogel in sandy loam and loam soils compared to clay soil. Moreover, increased permanent wilting point water content (θ_{pwp}), saturated water content (θ_S), as well as available water (AW) were observed. Statistical analyses indicated a considerable difference in growth indices using perlite+compost in clay soil. Compared with the control soil, a 2.4-time enhancement of AW was observed in loam soil using Pumice+ Hydrogel. A significant growth indices difference was also found for loam soil using pumice+hydrogel. According to WRC results, the highest treatment rate was attributed to compost+hydrogel in sandy loam soils, which led to a 3.3-time enhancement of AW.
Conclusion: Statistical analyses revealed that compost+hydrogel could lead to the best treatment on growth indices in sandy loam textures.

Keywords: Hydrogel; Pumice; Perlite; Compost; Manure fertilizer

1. Introduction

Global warming and decreased precipitation have led to climate change and consequent water shortage, especially in arid and semi-arid regions (Dorafshan et al., 2023). Water scarcity has led to crises and conflicts among consumers and even threats to the environment and water resource-dependent activities (Abedi-Koupai et al., 2020). One of the factors that has increased the use of water resources in these areas is the development of 'greening' cities (Nouri et al., 2019). Urban green space is considered the lungs of cities which play the respiratory function. These landscapes deserve consideration in terms of both meeting urban and environmental needs providing leisure spaces and creating a context for communication and its social equilibrium (Kiani et al., 2014). A great portion of the precipitation in Iran is scattered rain showers that create extensive surface currents, but it is feasible to improve the efficiency of water consumption in agriculture and make use of this sporadic precipitation and other limited water resources to store water in soil through proper management and advanced technologies, such as water retention, increasing the water holding capacity of soil, enhancing the hydraulic properties of soil, etc (Abedi-Koupai et al., 2022). In this regard, various measures are taken in arid areas, including increasing vegetation, utilizing mulch, and using such modifiers as zeolite, hydroplus, and Igeta (Abedi-Koupai et al., 2008a). Superabsorbent hydrogels are new types of modifiers that have recently gained wide use. These materials transform into a swollen gel with decent strength upon their rapid absorption of water as much as tens of times their weight and thus have a special role in agriculture, horticulture, forestry, green space development, and soil erosion control (Elshafie et al., 2020). Superabsorbents can hold the adsorbed water even under pressure, but easily release it to roots when required. Their quick water adsorption and effective retention improves the water adsorption efficiency of the soil exposed to the scattered precipitation and can help to prolong the irrigation intervals, whose extension depends on the physical conditions of soil, climate, quantity of superabsorbent present in the soil (Dorafshan and Eslamian, 2023). Superabsorbents make it possible to grow trees, develop green spaces, and improve the environmental conditions in arid areas with minimal water and the lowest possible cost (Demitri et al., 2013; Guilherme et al., 2015); hence, provide employment and development opportunities and motivate people to inhabit these areas. Water absorbents can also increase the percentage of executive operations in the field of soil improvement and environmental protection by reducing the number of irrigations and costs as well as the optimal use of water (Abrisham et al., 2018; Abedi-Koupai et al., 2008b; Abedi-Koupai and Asadkazemi, 2006). Application of superabsorbent Stockosorb in the root zone of olive trees significantly increased midday stomatal conductance and maximal quantum efficiency (Chehab et al., 2017; Zheng et al., 2023). Application levels of 4 and 6 gr of SuperAB A200 hydrogel per kg of soil the water requirement of *Cupressus* and *Ligusrum ovalifolium* was reduced by 33%. Also, it can result in a significant reduction in the required irrigation frequency (Abedi-Koupai et al., 2008a; Abedi-Koupai and Asadkazemi, 2006). Urban green space as a part of the skeletal system of cities has always been in contact with human beings (Kiani et al., 2014). But, in arid regions, with water scarcity, maintenance of the landscape has been a problem. Therefore, the use of alternative water-holding amendments such as superabsorbents can be effective. So, this manuscript attempts to have a sound and novel look at the effect of 5 types of water adsorbents and their combination on different soil textures and plants in urban green spaces. Specifically, the innovations of this research are as follows: 1) First, the effects of different superabsorbents along with their combination were investigated in the laboratory on WRC and also the water retention capacity, and then the best combinations were used for field tests. 2) Due to the high cost of hydrogel, natural superabsorbents (including nutrients and waste) were used, which are economical and can have similar results. 3) It was investigated whether the best type of superabsorbent in terms of soil water retention had similar results in laboratory tests with field tests (plant indices) for green space plants or not. 4) Unlike most research, this research has been conducted on non-productive plants (green space), which can be useful for supplying water to the green spaces of cities in arid and semi-arid regions of Iran, which are currently facing the challenge of water shortage. The main objectives of this research can be outlined as follows: 1) optimizing the consumption of water used for plants and trees in the selected parks and green spaces of the city with water scarcity; 2) determining the quantities of natural and synthetic superabsorbents used in the soil surrounding the roots; 3) monitoring the performance of the trees with superabsorbents stored around their roots; and 4) evaluating the impact of water adsorbents on soil water retention curves. Generalizing the laboratory results of adding natural and synthetic superabsorbent materials to the results of two years of adding these materials to field trials is the most important innovation of this research, which can be used to maintain green spaces in arid and semi-arid regions.

2. Materials and methods

Three areas of urban green spaces in Isfahan province, Iran, namely Mellat Park in Malek Shahr, Ghadir Park, and Enghelab Plain, were selected for this field research, which was conducted for two years in 2009 and 2010. Various problems are encountered in developing or/and preserving the green spaces in these areas due to ample water and soil issues.

Research sites

Mellat Park

This site is located in the north of Isfahan (32°43′07″N to 32°43′12″N, 51°38′53″E to 51°39′11″E; 1572 m altitude). The soil texture is clay. It also has no gravel and minimal organic materials. Its lime content, pH, electrical conductivity (EC), and SAR are 34.5 – 46%, 8.1 – 8.5, 15 dSm^{-1}, and 15.61, respectively. The area is without slope and accommodates Fraxinus, pines, and white mulberry trees. Among these three types of trees, this study opted for the Fraxinus rotundifolia. In addition to the issue of water shortage, the soil texture is also not without problems as it is very heavy and frustrates green space preservation. The reasons beyond the selection of this area are lowering the irrigation times, using the water resources more effectively, designing treatment(s) to modify the soil and make it lighter, and providing a proper bed to preserve its plants and grow new ones.

Ghadir Park

This site is located in the northeast of Isfahan (32°38′24″N to 32°38′42″N, 51°42′34″E to 51°43′03″E; 1575 m altitude). The soil texture of this area is the loam with high lime content. It contains 35 – 37% lime and also trivial organic materials that provide nutrition for the plants. The electrical conductivity, pH, and SAR of the soil are 1.23 dSm^{-1}, 7.8, and 3.47, respectively. Among the trees of the area, this research opted for platanus orientalis. Considering the vast and abundant trees as well as the shortage of water in this area, which is a prevalent issue in Isfahan, the conduction of this research which aimed to optimize the use of water sources and modify the soil with purposes similar to those of Mellat Park, is plausible.

Enghelab Plain

This 180-ha site with its 158,000 tree patches is located in the east of Isfahan (32°36′26″N to 32°37′00″N, 51°49′26″E to 51°50′52″E; 1590 m altitude). It is hot in summer and cold and dry in winter. Its soil permeability is moderate. The gravel content is $35-75\%$ in the depth and $15-35\%$ on the surface. The overall and lateral slope of the lands is $1-2\%$ with ups and downs and without erosion. The soil is non-saline and contains lime and gypsum accumulations. Its pH is about 7.5, and the soil has minimal nutritional and inorganic materials. Most of the trees in this area are Cupressus Arizonica, pine, locusts, pomegranate, Elaeagnus Angustifolia, mulberry, and Olea, and the irrigation system is drip irrigation. Among these trees, two species of Cupressus Arizonica and Olea europaea were selected for this research.

Characteristics of superabsorbents

In this research, 5 types of superabsorbent were used including manure fertilizer, compost, perlite, pumice, and hydrogel A200. The chemical and physical characteristics of each superabsorbent are presented in Tables 1 to 5.

Sample preparation

In this research, the soil of the test sites (Mellat Park, Ghadir Park, and Enghelab Plain) was randomly sampled from a depth of $0-40$ cm in several locations. The soil samples were air-dried, mixed, crushed, and sieved to less than 2 mm particle size. The characterization of each soil sample included texture type, physical properties (i.e., bulk density, porosity, water content at field capacity and permanent wilting point, total available water, and electrical conductivity of the saturated extract), and chemical properties including pH, cation exchange capacity, P, K, Mg, N, and Ca, and sodium adsorption ratio (SAR). After determining these characteristics, the experiments were conducted to determine the soil water retention curves (WRC). Every possible single and binary combination of superabsorbents was selected. In each soil type, a control sample and a sample made from the mixture of each treatment with the control soil were prepared and tested in the randomized complete block design with three iterations. One of the key goals of the laboratory phase of this research was to investigate the effects of superabsorbents on soil water retention curves. Afterward, the water retention curve of each soil was obtained considering its moisture changes. These curves were used to determine the best superabsorbent mixtures in terms of water retention. The results were used to choose suitable samples for the field phase.

Preparation and treatment methods of soil samples

In this study, one type of synthetic water absorbent including synthetic hydrogel Super AB A200 (hydrogel A200) with amounts of 4 and 6 gr/kg, four types of natural water absorbent (perlite, pumice, compost, and manure fertilizer) with amounts of 40 and 60 gr/kg were used. To treat the samples, these absorbents were introduced to a single texture of soil (samples of 100 gr of soil) in high application levels with three iterations.

Effects of adding water absorbents on WRC and soil moisture parameters

For this purpose, the results of three soil textures of three sites, Mellat Park, Ghadir Park, and Enghelab Plain obtained in the laboratory using a pressure plate device with 9 suctions (0, 0.1, 0.3, 0.5, 1, 3, 5, 10 and 15 bar) were fitted with RETC software models. The effects of adding water absorbents on the parameters of soil water retention curves (n, α, θ_S, θ_r) were investigated.

Field experiments

After obtaining the water retention curves of all treatments for each soil as well as performing the statistical analysis with SAS software, the most effective treatments were determined. In other words, we selected the mixture(s) that had the most enhancing effect on the water retention curves to investigate their impacts on trees in the field phase. The rest of the treatments were not pursued in this phase. Adding each treatment on the selected trees of each site experiments were conducted with four replications. In species selection, it was strived to perform each treatment on the look-alike trees. The control trees were as similar as possible to them too. The field experiment was carried out over two years using the split-plot design based on the randomized complete block design. After the application of the treatments, trees were observed every 15 days (growing season) for the first-year field experiment and 30 days for the second year, respectively. The growth indexes that were measured in the field experiment include the diameter of the scaffolds in two spots, i.e. where the trunk comes out of the soil (hereinafter referred to as 'down diameter, D_{Down}') and where the secondary scaffolds branch out (hereinafter referred to as 'top diameter, D_{top}'), and the number of the secondary scaffolds at the first branching junction (hereinafter referred to as 'S'). The statistical analysis was performed with SAS software.

Methods of application of treatments at sites

Pits filling is a method of locally applying organic and chemical fertilizers into the soil which is called "Chalkoud". In this research, pits filling method was used as presented in Figs 1 and 2.

In all three selected sites, the trees were less than ten years old. Therefore, for each tree, two pits (holes) with a diameter of about 35 cm and a depth of about $40-50$ cm were drilled.

Table 1. Chemical, Physical, and Microbial analysis of the manure fertilizer used as superabsorbent.

Chemical analysis			Physical analysis			Microbial analysis and fertility characteristics		
Parameter	Content	Unit	Parameter	Content	Unit	Parameter	Content	Unit
Organic Matter(OM)	40.4	%	Organic Matter(OM)	98.4	%	Total Coliform	670	MPN/gTS
Total Carbon (TC)	25.3	%	Paper	0.21	%	Fecal Coliform	420	MPN/gTS
Organic Carbon (OC)	2.4	%	Textile	0.11	%	Salmonella	3	MPN/4gTS
Ash	54.4	%	Wood	0.15	%	Streptococcus	220	MPN/gTS
C/N	10.1	-	Hard plastics	0.32	%	germination Test	80	%
NH_3/NO_4	250	-	Glass shards	0.45	%			
pH	8.4	-	Stone	0.36	%			
Electric Conductivity (EC)	10	dS/m	Metal fragments	0.0	%			
Total Nitrogen (TN)	2.2	%	Moisture	28	%			
P	0.31	%	Density	580	Kg/m^3			
K	0.98	%	Temperature	40	°C			
N:P:K	220:31:98	-						
Ca	4.8	%						
Na	0.58	%						
Mg	0.37	%						
Iron	0.83	%						
Copper	208	mg/kg						
Lead	23	mg/kg						
Cadmium	2	mg/kg						
Nickel	33	mg/kg						

Table 2. Chemical, Physical, and Microbial analysis of the compost used as superabsorbent.

Chemical analysis			Physical analysis			Microbial analysis and fertility characteristics		
Parameter	Content	Unit	Parameter	Content	Unit	Parameter	Content	Unit
Organic Matter (OM)	68	%	Organic Matter (OM)	97.5	%	Total Coliform	840	MPN/gTS
Total Carbon (TC)	41.1	%	Paper	0.65	%	Fecal Coliform	360	MPN/gTS
Organic Carbon (OC)	37	%	Textile	0.45	%	Salmonella	3	MPN/4gTS
Ash	26	%	Wood	0.20	%	Streptococcus	240	MPN/gTS
C/N	18	-	Hard plastics	0.54	%	germination Test	80	%
NH_3/NO_4	200	-	Glass shards	0.72	%			
pH	7.2	-	Stone	0.38	%			
Electric Conductivity (EC)	9	dS/m	Metal fragments	0.0	%			
Total Nitrogen (TN)	1.8	%	Moisture	25	%			
P	0.35	%	Density	520	Kg/m^3			
K	0.9	%	Temperature	42	°C			
N:P:K	180:35:90	-	Parameter	Content	Unit			
Ca	4.2	%	Organic matter	97.5	%			
Na	0.44	%	Paper	0.65	%			
Mg	0.29	%	Textile	0.45	%			
Iron	0.87	%	Wood	0.20	%			
Copper	235	mg/kg	Hard plastics	0.54	%			
Lead	68	mg/kg	Glass shards	0.72	%			
Cadmium	7	mg/kg	Stone	0.38	%			
Nickel	31	mg/kg	Metal fragments	0.0	%			

Table 3. Chemical composition of the perlite and pumice used as superabsorbent.

Chemical compound	perlite	pumice
	Content (%)	
SiO_2	68.21	48.37
Al_2O_3	1.22	12.49
Fe_2O_3	1.22	8.07
TiO_2	0.20	1.78
CaO	1.21	8.43
MgO	0.06	9.58
Na_2O	5.21	4.63
K_2O	4.6	3.27
SO_3	2.11	0.31
P_2O_5	-	1.79
MnO	-	0.12

Table 4. Chemical analysis of the pumice used as superabsorbent.

Parameter	Content	Unit
EC	0.13	dS/m
pH	7.9	%
OC	0.0	-
Pb	4.7	mg/kg
Cd	0.4	mg/kg
Ni	0.9	mg/kg
Cr	0.0	mg/kg
Co	0.0	mg/kg

Table 5. Chemical characteristics of the hydrogel A200 used as superabsorbent.

Parameter	Content	Unit
Color	White	-
Water content	5 – 7	%
Smell and toxicity	No	-
Density	1.4 – 1.5	gr/cm^3
pH	6 – 7	-
Solubility in water Insoluble	-	
Particle size	50 – 150	μm
Durability	7	Year
Feasible absorption capacity of drinking water	190	gr/gr
Feasible absorption capacity of distilled water	220	gr/gr
Feasible absorption capacity of 0.9% sodium chloride solution	45	gr/gr
Time to achieve 0.63 of equilibrium absorption capacity	70	seconds
Maximum soluble content	1 – 2	%

Table 6. Chemical properties of soils of three parks.

Location	P (mg/kg)	Mg (meq/L)	N (%)	Na (meq/L)	K (mg/kg)	pH (-)	Ca (meq/L)	EC_e (dS/m)	CEC (meq/100gr soil)	SAR (-)
Ghadir	10	3.4	0.12	7.29	224	8.1	5.4	1.23	36.71	3.48
Mellat	36	5.4	0.19	34.9	553.8	7.9	4.6	3.7	55.5	15.61
Engelab	48	2	0.02	2.11	301.6	8.2	3	0.64	17.92	1.32

Table 7. Physical properties of soils of three areas.

Location	Soil Texture	Sand (%)	Silt (%)	Clay (%)	ρ_b (gr/cm^3)
Ghadir	Loam	48	34	18	1.7
Mellat	Clay	16	35	49	1.6
Engelab	Sandy loam	74	14	12	1.5

Figure 1. Performing pits filling method and their location near a tree.

3. Results and discussion

Soil analysis

After analyzing the soils of all three areas, their physical and chemical properties are presented in Tables 6 and 7.

Effect of applying water absorbents on WRC and soil moisture parameters

The first investigated area was Mellat Park, where the soil is heavy and clay-textured. Fig. 3 shows the water retention curves of various treatments of the soil of Mellat Park. The second area investigated in this research was Ghadir Park with loamy-textured soil. The results were obtained from the water retention curves of this area (Fig. 4). The last investigated area was Enghelab Plain with the soil texture of sandy loam. Fig. 5 illustrates the WRC of various treatments of the soil of Enghelab Plain. The results obtained from these curves are separately presented below.

Saturated soil water content (θ_S)

The saturated water content of the soil of Mellat Park, Ghadir Park, and Enghelab Plain in the initial form and without any modifiers (the control soil) were 58 wt%, 49 wt%, and 38 wt%, respectively. The highest saturated water content of Mellat Park was 90 wt% (1.56 times greater than the control soil) and related to the treatment of pumice + hydrogel. The most effective mixture in the soil of Ghadir Park was pumice + hydrogel, resulting in a saturated water content of 92 wt% (1.87 times greater than the control soil). The highest saturated water content of Enghelab Plain was related to the mixture of perlite + hydrogel, which increased the saturated water content to 85 wt% (2.19 times greater than the control soil).

Water content at permanent wilting point (θ_{PWP})

The water content of the soil of Mellat Park, Ghadir Park, and Enghelab Plain at the permanent wilting point in the initial form and without the application of additives (the control soil) was 21.4 wt%, 13.7 wt%, and 7.2 wt%, respectively. The most significant increase in the water content of the soil of Mellat Park was in the case of hydrogel with the application level of 6 gr/kg as the water content increased to 37.7 wt% (1.76 times greater than the control soil). The most effective combination of absorbent materials for the soil of Ghadir Park was hydrogel + perlite with a water content of 36 wt% (2.63 times greater than the soil control), a remarkable enhancement. The most significant increase in the water content of the soil of Enghelab Plain was related to the mixture of hydrogel + perlite as the water content increased to 36.1 wt% (5.01 times greater than the control soil), which is a very significant improvement.

Figure 2. The pits (which are called Chalkoud) are filled with various treatments.

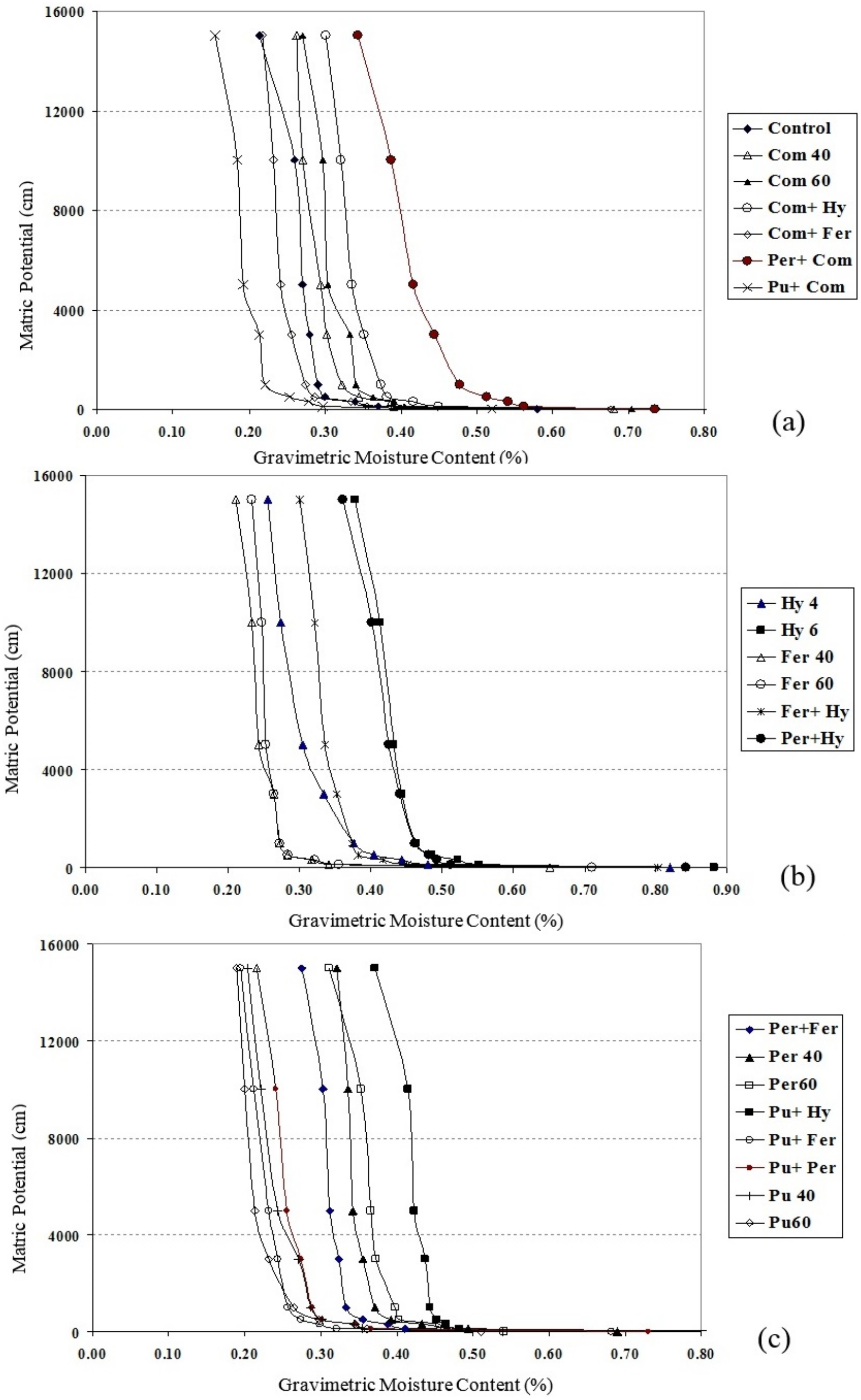

Figure 3. Effect of applying water absorbents on WRC of the soil of Mellat Park.

Soil water content at field capacity (θ_{FC}) and Available water content

The soil water content at field capacity is more important than the saturated water content of the soil as it is the field capacity point when the roots can breathe and plants can grow properly. The most effective mixture in terms of this parameter in the soil of Mellat Park was perlite + compost with a water content of 54 wt% in comparison with 34 wt% of the control soil (1.59 times greater than the control soil). The soil of Ghadir Park with its loamy texture normally has a water content of 22 wt% at field capacity. The most significant improvements of this parameter were related to the combination of hydrogel + perlite, which resulted in a water content of 54 wt% (2.47 times greater than the control soil). The soil of Enghelab Plain, which has a sandy loam texture, has a water content of 12 wt% at this point. The most significant improvements of this parameter were related to the treatments of hydrogel + perlite and hydrogel + manure fertilizer, which resulted in the water contents of 44 wt% (3.5 times greater than the

control soil).
The available water content of a plant is the difference between the water content at field capacity and permanent wilting point, however, in practice, this content cannot be easily obtained. As highlighted, the use of the treatments was effective on the enhanced water content of the soil at important points. Regarding their impact on the available water content, this parameter for the control soil of Mellat Park was 12.6 wt%. The application of perlite + compost treatment resulted in a water content of 19.7 wt% (1.56 times greater than the control soil). The use of compost + hydrogel treatment presented similar results and increased the available water content by 1.6 times greater than the control soil. The available water content of the soil of Ghadir Park without any modifiers was 8.4 wt%. Two of the treatments that had a significant effect on the available water content of the soil were the mixtures of pumice + hydrogel and perlite + hydrogel. These two treatments increased this parameter to 20.3 wt% (2.42 times greater than the control soil) and 18.5 wt% (2.24 times greater than the control soil), respectively. The available water content of the soil of Enghelab Plain without any modifiers was 5.2 wt%. Two treatments with considerable effects on the available water content of the soil of this area were compost + hydrogel and pumice + hydrogel. These two treatments increased this content to 17.2 wt% (3.3 times greater than the control soil) and 15.6 wt% (3 times greater than the control soil), respectively, both being very significant improvements. Therefore, for the clay-textured soil of Mellat Park, increasing the application content of the hydrogel did not have a positive effect on the soil's available water content. This can be due to the irrigation water salinity or high electrical conductivity of the saturated extract of the soil, which leads to compromised swelling behavior of the hydrogel. Also, we found that increasing the application quantity of perlite improved the absorbed water content of the soil. Furthermore, larger quantities of pumice enhanced the available water content of the heavy soil of Mellat Park. This is also consistent with the results of (Sahin and Anapali, 2006; Sahin et al., 2005; Guilherme et al., 2015; Elshafie and Camele, 2021). In the loamy-textured soil of Ghadir Park, the higher application levels of pumice exacerbated the available water content of the soil. Conversely, there was a positive correlation between this parameter and the hydrogel application quantity. The mixture of these two absorbents created the best results in terms of water retention behavior of the soil, which are also consistent with the studies of (Sahin et al., 2005; Agaba et al., 2010; Abdallah, 2019b; Zheng et al., 2023). Concerning the perlite, the results showed that the available water content of the soil increased using higher application levels of this material. In the case of the light-textured soil of Enghelab Plain, we observed that higher application levels of the hydrogel increased the water content of the soil as between the two quantities of 4 and 6 gr/kg, the latter was more effective. This was perfectly consistent with the results of Abedi-Koupai et al. (2008a), (Al-Harbi et al., 1999), (Abdallah, 2019a).

Statistical analysis of laboratory results of water retention curves

The laboratory results of the water retention curves obtained with the pressure plate device were analyzed using the SAS software.

Statistical analysis of results of Mellat Park

The statistical analysis of the laboratory data of Mellat Park (Fig. 6) demonstrated that the largest increase in the available water content of the soil of this area was related to the treatments of the perlite and its mixtures. According to the graphs of Fig. 6, the most effective treatment was the mixture of perlite + compost, which increased the available water content to 21 wt%. Considering the available water content of the control soil (13 wt%), the application of this treatment improved the available water content of this clay-textured soil by 1.6 times. The statistical analysis showed that this increase was significant at 5% level ($p \leq 0.05$). The treatment of A200 (hydrogel) superabsorbent with the application level of 4 gr/kg also had good results in improving the available water content of the soil as it increased this parameter to 20 wt%, which was 1.5 times larger than the available water content of the control soil. The application of these two treatments was statistically at the same level, and they both had the best results in this soil. The third most effective treatment was perlite with an application level of 60 gr/kg with an available water content of 1.3 times larger than the control. In terms of statistical significance, this treatment was the second best. The treatments of hydrogel and pumice with the application levels of 6 gr/kg and 60 gr/kg (respectively), yielded similar available water contents of 15 wt%, both at the same level of significance.

Statistical analysis of results of Ghadir Park

All of the treatments applied to the soil of this area ameliorated its water retention ability. As it is demonstrated in Fig. 7, the most positively effective treatment was the mixture of pumice+hydrogel, increasing the available water content from 7 wt% of the control soil to 22 wt% (3.1 times greater than the control soil). The mixture of perlite + hydrogel also improved this parameter up to 19 wt% (2.7 times greater than the control soil). The statistical analysis showed that this increase was significant at a 5% level. The treatment of super AB A200 with the application level of 4 gr/kg also had a satisfactory effect on this content as it reached 17 wt% (2.4 times greater than the control soil). The results of three treatments of compost+manure fertilizer, perlite with the application level of 60 gr/kg, and pumice + perlite were similar to those of the hydrogel treatment with the application level of 4 gr/kg and thus, statistically, they were at the same level of significance. In this soil, apart from the mixture of compost that was mentioned, the other treatments were at the last levels and did not have any significant effects on the available water content.

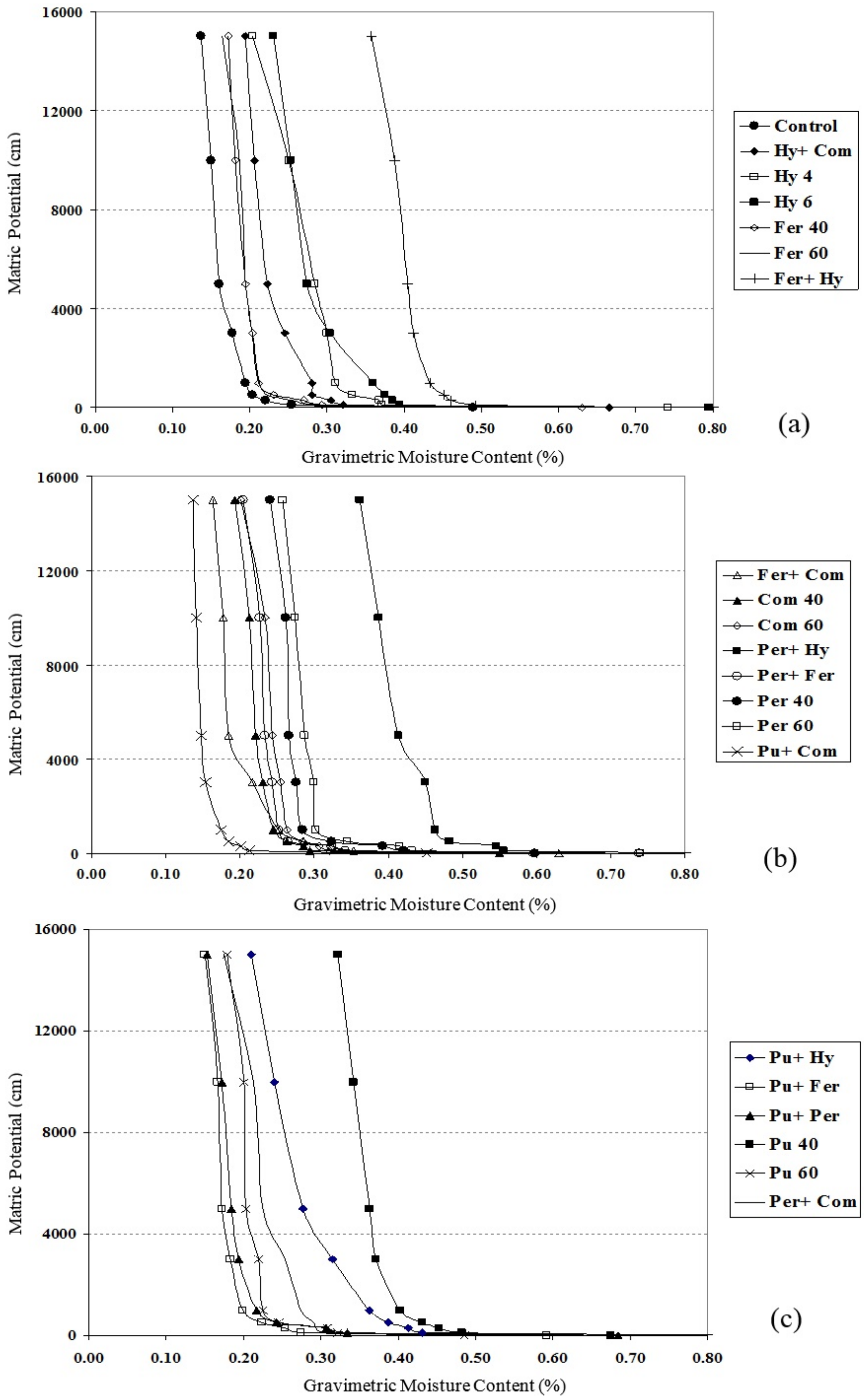

Figure 4. Effect of applying water absorbents on WRC of the soil of Ghadir Park.

Statistical analysis of results of Enghelab Plain

The soil of this region is sandy loam and very light, and according to Table 1, it is not saline. As it is clear in the analysis results presented in Fig. 8, the treatment of compost + hydrogel had a significant impact on the available water content of the soil as it improved it from 6 wt% of the control soil to 22 wt% (3.6 times greater than the control soil). Statistically, this increase was significant at a 5% level ($p \leq 0.05$). The hydrogel treatment with the application level of 6 gr/kg resulted in an improved available water content of 20 wt% (3.3 times greater than the control soil). The mixture of pumice + hydrogel also produced a satisfactory and significant result as it increased the available water content from 6 wt% of the control soil up to 17 wt%. Moreover, the use of hydrogel at the application level of 4 gr/kg increased the available water content to 16 wt%, which was statistically at the same level of significance as the

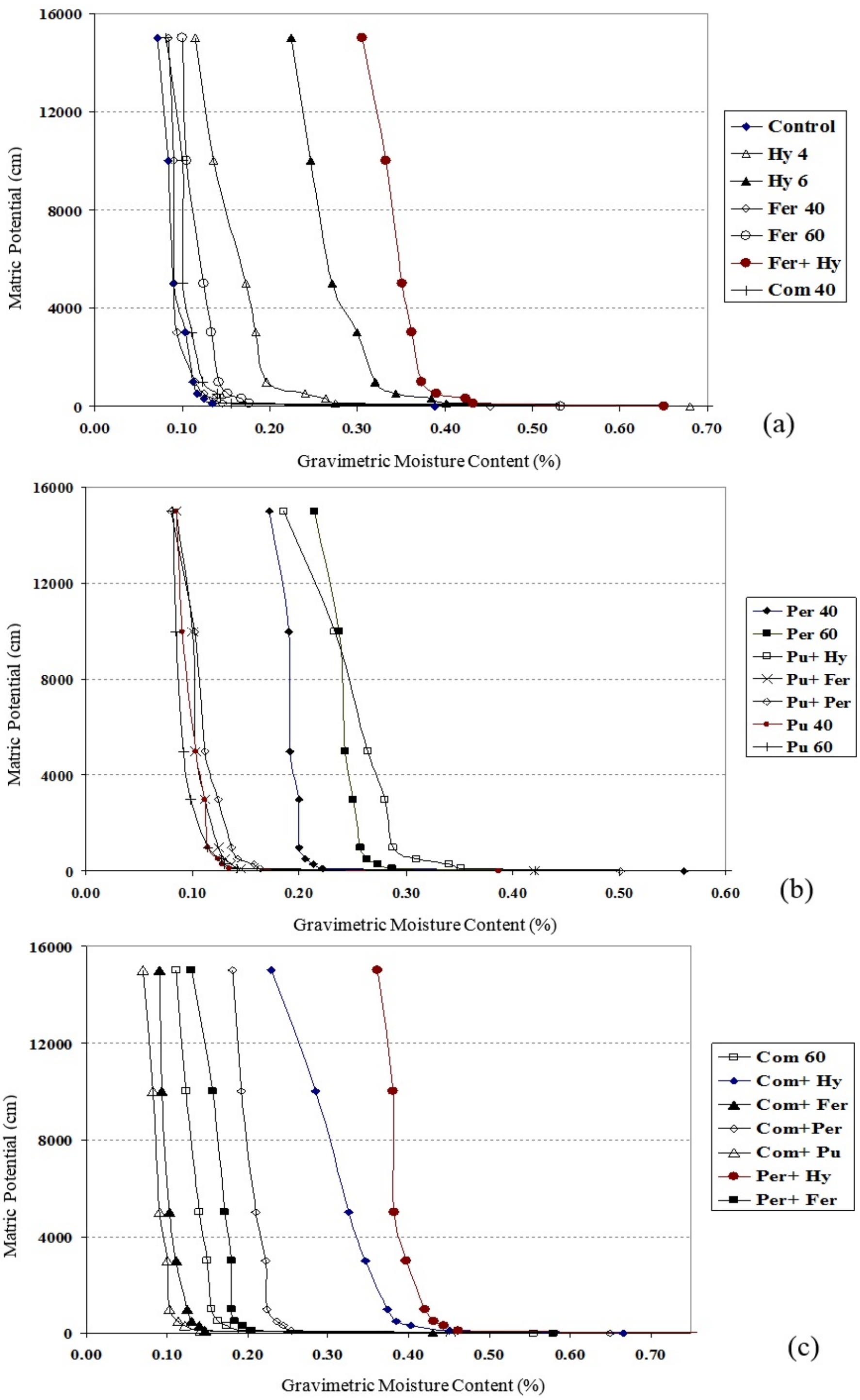

Figure 5. Effect of applying water absorbents on WRC of the soil of Enghelab Plain.

pumice + hydrogel treatment. The results in Fig. 8 showed that the application of water-absorbent hydrogel and its related mixtures ameliorated the available water content of the soil of Enghelab Plain. Conversely, adding pumice to this soil texture did not have a good result on its water retention ability as pumice made the texture lighter and reduced this content compared to that of the control soil.

Statistical analysis of results of field experiments in the first and second years

In the first and second years of the field phase, we visited the selected areas and collected data once every 15 and 30 days (growing season), respectively. The measured indices included the number of the secondary scaffolds (hereinafter referred to as 'S') and the diameter of the scaffold where the trunk comes out of the soil (hereinafter referred to as 'down diameter, D_{Down}') and where the secondary scaffold branches out at the first branching junction (hereinafter referred to as 'top diameter, D_{top}').

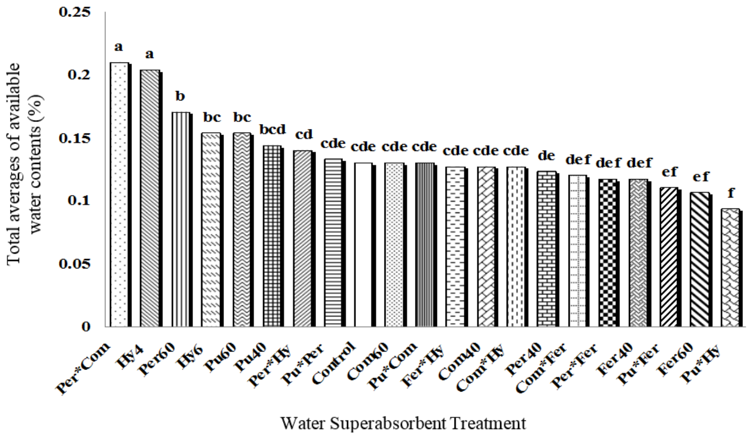

Figure 6. Statistical comparison of total averages of available water contents of different superabsorbents in Mellat Park (Per: Perlite, Com: Compost, Hy: Hydrogel, Pu: Pumice, Fer: Fertilizer). The treatments with dissimilar signs have a significant difference in statistics ($p < 0.05$).

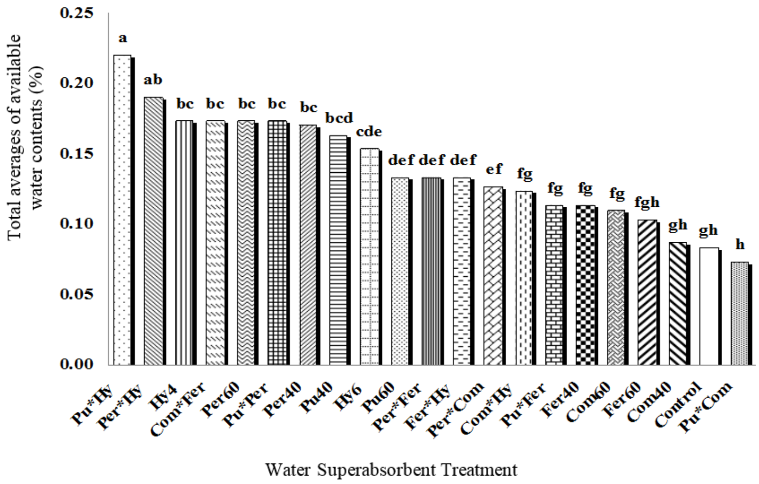

Figure 7. Statistical comparison of total averages of available water contents of different superabsorbents in Ghadir Park (Per: Perlite, Com: Compost, Hy: Hydrogel, Pu: Pumice, Fer: Fertilizer). The treatments with dissimilar signs have a significant difference in statistics ($p < 0.05$).

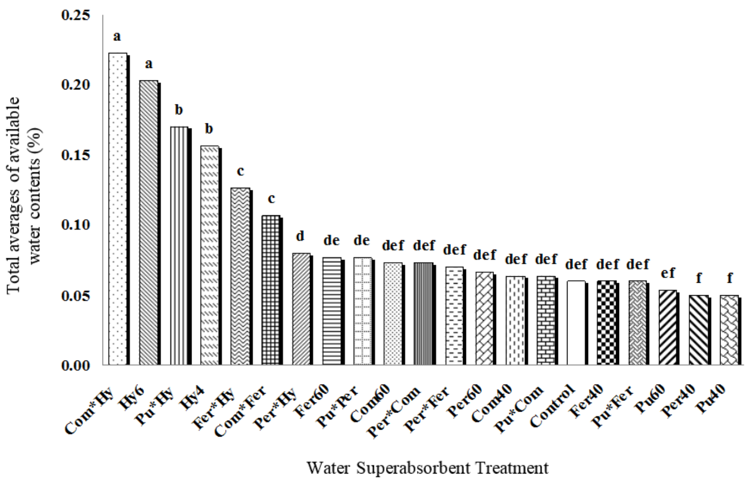

Figure 8. Statistical comparison of total averages of available water contents of different superabsorbents in Enghelab Plain (Per: Perlite, Com: Compost, Hy: Hydrogel, Pu: Pumice, Fer: Fertilizer). The treatments with dissimilar signs have a significant difference in statistics ($p < 0.05$).

The gathered data were analyzed using SAS and SPSS as well as the LSD test.

Statistical analysis of field experiment results of Mellat Park

The statistical analysis results of the effects of adding superabsorbents to the soil of this area on the growth indices are presented in Tables 8 and 9. Apart from the index of the number of the secondary scaffolds, the results of the treatment applications were significant at a 1% level for the variations of the other indices, but the interaction effect of time $\times$ treatment was significant only for the down diameter, so the LSD test was used for comparisons. The results indicated that the treatment of perlite with the application level of 60 gr/kg had the best effect on the growth of the plants. After perlite, the second most effective treatment was perlite + compost.

Statistical analysis of field experiment results of Ghadir Park

The statistical analysis results of the effects of applying superabsorbents to the soil of this park on the growth indices are presented in Tables 10 and 11. The results of the treatment applications were not significant for the variations of the index of the number of the secondary scaffolds, but the variations of two other diameter indices were significant. The effect of time was significant for all three indices, yet the interaction effect of time $\times$ treatment was not. The results indicated that applying the treatments of pumice + Hydrogel as well as compost + manure fertilizer engendered significant variations compared to the control soil in this area.

Statistical analysis of field experiment results of Enghelab Plain

In this area, two species were selected for the field phase, namely *Cupressus Arizonica* and *Olea europaea*. Two indices of the top and down diameters were measured for *Cupressus Arizonica*. In the case of *Olea europaea*, the statistical analysis showed that treatments were significant only for the increases in two diameter indices. While the interaction effect of time$\times$treatment was not significant for any of the indices, all treatments produced variations compared to the control tree. The mixtures of compost + hydrogel and compost + manure fertilizer were the most effective treatments for *Olea europaea*. For *Cupressus Arizonica*, the best treatments were compost + hydrogel and hydrogel with an application level of 6 gr/kg. The analysis Tables of each species are presented in Tables 12 to 15.
Applying a number of absorbent polymers leads to the considerable enhancement of Citrus limon yield through increasing the soil water holding capacity and consequent long-term maintenance of soil moisture, soil microbial activity increase, and fruit loss prevention (Pattanaaik et al., 2015; Elshafie and Camele, 2021; Zheng et al., 2023). Pieve et al. (2013) investigated how polymers influence coffee plants' growth in the open field. According to their results, applying polymer solution simultaneous with the new planting could decrease related mortality. It is noteworthy that using highly absorbent polymers in the coating process leads to a significant increase in water availability for the seed's early growth under dry circumstances. Consequently, related emergence delays and crop standing are decreased (Willenborg et al., 2004). Several investigations are carried out on the implementation of different absorbent polymer doses, which improve soil remediation and plant growth. They revealed that applying absorbent polymers, specifically to $0-20$ cm soil surfaces, leads to promising effects on the soil temperature, as well as the enhancement of photosynthetic rate and crop yield (Eneji et al., 2013).

4. Conclusion

There are various types of water absorbents and related compounds of the soil texture and salinity were observed in urban green spaces with appropriate functions. Therefore, a maximum enhancement in the content of saturated water within the clay-textured soil of Mellat Park was produced as a result of pumice + hydrogel, which led to a 1.56-time increase in the parameter. A 1.59-time increase in the water content at field capacity was observed as a result of perlite + compost treatment. Compared to the control soil, a 1.76-time increase of soil water was found at the permanent wilting point due to the addition of hydrogel with a 6 gr/kg application level. Therefore, the mixture was associated with a high rate of moisture retention under significant suction pressures. It was also found that the excessive increase of water-absorbing hydrogel does not improve the physical conditions of the soil. Therefore, higher application levels of the mentioned hydrogel were not efficient. A 1.56-time increase of the mentioned soil available water content was achieved as a result of using compost+perlite treatment. The implementation of the mentioned treatments in Mellat Park at various periods could not lead to considerable differences in the indices of the secondary scaffolds and down diameter quantities; however, the top diameter showed significant variations. More appropriate performances were observed for perlite treatment with a 60 gr/kg application level and perlite + compost; therefore, considerable variations were generated in the measured growth indices at $p \leq 0.05$. Considering the loamy textured soil of Ghadir Park, pumice+hydrogel treatment led to a 1.87-time increase in the soil-saturated water content. Moreover, hydrogel + perlite treatment respectively led to the 2.47 and 2.63 enhancement of water content at field capacity and permanent wilting point. Using pumice + hydrogel treatment, a 2.42-time enhancement was observed for AW. There were not considerable variations that occurred as a result of implementing the treatments at various times for vegetation growth indices; however, the treatment type-caused variations were considerable for all of the indices. Considering the field phase, pumice+hydrogel led to important variations. Perlite+hydrogel caused the 2.19-, 3.5-, and 5.01-time enhancement of saturated water content, field capacity, and

Table 8. Analysis of variance results of effects of superabsorbent treatments on some growth indices of *Fraxinus rotundifolia* trees in Mellat Park (first and second year filed experiment).

Year	1	2	1	2	1	2	1	2
SV	Df		MS.ΔS		MS.ΔD_{Down}		MS.ΔD_{top}	
Treatment	5	5	$0.04^{n.s}$	$0.02^{n.s}$	0.09^{**}	0.08^{**}	0.05^{**}	0.05^{**}
Main Error factor	6	10	0.05	0.04	0.00	0.00	0.00	0.00
Time	7	11	0.05	0.06^{**}	0.02^{**}	0.01^{**}	0.02^{**}	0.09^{**}
Treatment×Time	35	55	$0.12^{n.s}$	$0.07^{n.s}$	0.01^{*}	$0.01^{n.s}$	$0.00^{n.s}$	$0.01^{n.s}$
Total Errors	42	66	0.17	0.14	0.00	0.02	0.01	0.01
Total	95	147	—	—	—	—	—	—

1: first year, 2: second year **: Significant at 1% level. ΔD_{top}: Top diameter Variations *: Significant at 5% level. ΔD_{Down}: Down diameter variations *n.s*: Not significant. ΔS: Variations in the number of the secondary scaffolds.

Table 9. The comparison of average growth indices (top and down diameter variations) for *Fraxinus rotundifolia* under superabsorbent treatments (first and second year filed experiment).

Year	1	2	1	2	1	2	1	2	1	2	1	2
Treatment Growth Index	Perlite 60 gr/kg		Pumice 60 gr/kg		Compost 60 gr/kg		Perlite+ Compost		Pumice+ Perlite		Control	
mean ΔD_{Down}	0.36^{a}	0.29^{a}	0.22^{c}	0.22^{c}	0.15^{d}	0.12^{d}	0.28^{b}	0.26^{b}	0.21^{c}	0.24^{c}	0.18^{cd}	0.18^{cd}
mean ΔD_{top}	0.32^{a}	0.33^{a}	0.20^{c}	0.18^{c}	0.16^{c}	0.16^{c}	0.27^{b}	0.25^{b}	0.20^{c}	0.23^{c}	0.20^{c}	0.21^{c}

1: first year, 2: second year. The treatments with dissimilar signs have a significant difference at a 5% level.

Table 10. Analysis of variance results of effects of superabsorbent treatments on some growth indices of *platanus orientalis* trees in Ghadir Park (first and second year filed experiment).

Year	1	2	1	2	1	2	1	2
SV	Df		MS.ΔS		MS.ΔD_{Down}		MS.ΔD_{top}	
Treatment	5	5	$0.02^{n.s}$	$0.00^{n.s}$	0.85^{**}	0.72^{*}	0.10^{**}	0.25^{**}
Main Error factor	6	10	0.10	0.11	0.01	0.01	0.01	0.01
Time	7	11	0.23^{*}	0.27^{*}	0.09^{**}	0.07^{**}	0.07^{**}	0.06^{**}
Treatment×Time	35	55	$0.10^{n.s}$	$0.12^{n.s}$	$0.01^{n.s}$	$0.01^{n.s}$	$0.01^{n.s}$	$0.02^{n.s}$
Total Errors	42	66	0.10	0.10	0.01	0.01	0.01	0.01
Total	95	147	—	—	—	—	—	—

1: first year, 2: second year **: Significant at 1% level. ΔD_{top}: Top diameter Variations *: Significant at 5% level. ΔD_{Down}: Down diameter variations *n.s*: Not significant. ΔS: Variations in the number of the secondary scaffolds.

Table 11. The comparison of average growth indices (top and down diameter variations) for platanus orientalis under superabsorbent treatments (first and second year filed experiment).

Year	1	2	1	2	1	2	1	2	1	2	1	2
Treatment Growth Index	Perlite 60 gr/kg		Manure Fertilizer 40 gr/kg		Pumice+ Hydrogel		Compost+ Manure Fertilizer		Pumice+ Perlite		Control	
mean ΔD_{Down}	0.24^{bc}	0.20^{bc}	0.16^{c}	0.17^{c}	0.36^{a}	0.27^{a}	0.30^{ab}	0.25^{ab}	0.22^{bc}	0.24^{bc}	0.20^{c}	0.15^{c}
mean ΔD_{top}	0.21^{cd}	0.18^{d}	0.17^{d}	0.23^{cd}	0.36^{a}	0.42^{a}	0.31^{ab}	0.34^{ab}	0.26^{bc}	0.29^{bc}	0.16^{d}	0.16^{d}

1: first year, 2: second year. The treatments with dissimilar signs have a significant difference at a 5% level.

Table 12. Analysis of variance results of effects of superabsorbent treatments on some growth indices of *Olea europaea* trees in Enghelab Plain (first and second year filed experiment).

Year	1	2	1	2	1	2	1	2
SV	Df		MS.ΔS		MS.ΔD_{Down}		MS.ΔD_{top}	
Treatment	5	5	$0.03^{n.s}$	$0.00^{n.s}$	0.13^{*}	0.11^{*}	0.10^{**}	0.14^{**}
Main Error factor	6	10	0.07	0.10	0.01	0.02	0.00	0.03
Time	7	11	$0.09^{n.s}$	$0.04^{n.s}$	$0.03^{n.s}$	$0.03^{n.s}$	0.03^{**}	0.03^{**}
Treatment×Time	35	55	$0.11^{n.s}$	$0.11^{n.s}$	$0.03^{n.s}$	$0.07^{n.s}$	$0.01^{n.s}$	$0.02^{n.s}$
Total Errors	42	66	0.14	0.20	0.03	0.03	0.00	0.04
Total	95	147	—	—	—	—	—	—

1: first year, 2: second year **: Significant at 1% level. ΔD_{top}: Top diameter Variations *: Significant at 5% level. ΔD_{Down}: Down diameter variations *n.s*: Not significant. ΔS: Variations in the number of the secondary scaffolds.

Table 13. The comparison of average growth indices (top and down diameter variations) for *Olea europaea* under superabsorbent treatments (first and second year filed experiment).

Year	1	2	1	2	1	2	1	2	1	2	1	2
Treatment Growth Index	Hydrogel 6 gr/kg		Pumice 60 gr/kg		Compost+ Hydrogel		Compost+ Manure Fertilizer		Pumice+ Hydrogel		Control	
mean ΔD_{Down}	0.35^{ab}	0.31^{ab}	0.25^{bc}	0.27^{b}	0.43^{a}	0.35^{a}	0.37^{a}	0.34^{a}	0.33^{ab}	0.21^{bc}	0.17^{c}	0.16^{c}
mean ΔD_{top}	0.32^{b}	0.30^{b}	0.21^{c}	0.22^{c}	0.39^{a}	0.39^{a}	0.29^{b}	0.29^{b}	0.33^{ab}	0.34^{ab}	0.17^{c}	0.16^{c}

1: first year, 2: second year. The treatments with dissimilar signs have a significant difference at a 5% level.

Table 14. Analysis of variance results of effects of superabsorbent treatments on some growth indices of *Cupressus Arizonica* trees in Enghelab Plain (first and second year filed experiment).

Year	1	2	1	2	1	2
SV	Df		MS.ΔD_{Down}		MS.ΔD_{top}	
Treatment	5	5	0.22^{**}	0.27^{**}	0.22^{**}	0.24^{**}
Main Error factor	6	10	0.00	0.02	0.00	0.02
Time	7	11	0.03^{**}	0.04^{**}	0.03^{**}	0.03^{**}
Treatment×Time	35	55	$0.00^{n.s}$	$0.03^{n.s}$	$0.00^{n.s}$	$0.01^{n.s}$
Total Errors	42	66	0.00	0.00	0.00	0.00
Total	95	147	—	—	—	—

1: first year, 2: second year **: Significant at 1% level. ΔD_{top}: Top diameter Variations *: Significant at 5% level. ΔD_{Down}: Down diameter variations *n.s*: Not significant. ΔS: Variations in the number of the secondary scaffolds.

Table 15. The comparison of average growth indices (top and down diameter variations) for *Cupressus Arizonica* under superabsorbent treatments (first and second year filed experiment).

Year	1	2	1	2	1	2	1	2	1	2	1	2
Treatment Growth Index	Hydrogel 6 gr/kg		Pumice 60 gr/kg		Compost+ Hydrogel		Pumice+ Hydrogel		Compost+ Manure Fertilizer		Control	
mean ΔD_{Down}	0.36^{b}	0.32^{b}	0.11^{d}	0.16^{d}	0.40^{a}	0.38^{a}	0.30^{c}	0.21^{c}	0.28^{c}	0.27^{c}	0.13^{d}	0.15^{d}
mean ΔD_{top}	0.37^{ab}	0.48^{ab}	0.12^{d}	0.09^{d}	0.42^{a}	0.79^{a}	0.31^{bc}	0.33^{bc}	0.26^{c}	0.21^{c}	0.15^{d}	0.10^{d}

1: first year, 2: second year. The treatments with dissimilar signs have a significant difference at a 5% level.

permanent wilting point of the coarse-sandy loam-textured soil of Enghelab Plain, respectively. Due to the fact that the increase of hydrogel content applied to the mentioned soil led to the increased total water content, compost + hydrogel treatments enhanced the parameter by 3.3 times compared to the control soil. The treatment application at various times in Enghelab Plain led to considerable variations in the top diameter index that were found to be significant at 1% and 5% levels for Olea europaea and Cupressus Arizonica, respectively. The compost + hydrogel treatment applied to the field phase produced considerable variations.

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Ethical approval
This manuscript does not report on or involve the use of any animal or human data or tissue. So the ethical approval is not applicable.

Author contribution
Jahangir Abedi Koupai: Supervision, Conceptualization, Methodology, Software, Final Reviewing and Editing. Farid Reza Salimi: Data collection from laboratory devices, data Collection from three field experimental sights, Data curation, Writing-Original draft preparation. Mohammad Mahdi Matinzadeh: Writing- Reviewing and Editing. Mohammad Mahdi Dorafshan: Writing- Reviewing and Editing.

Availability of data and materials
Data presented in the manuscript are available via request.

Conflict of interest statement
The authors declare that there are no conflicts of interest associated with this study.

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