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Review article

A review: use of soilless culture techniques in ornamental plants

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Abstract

The use of soilless culture in the cultivation of ornamental plants is becoming widespread, especially in the production of cut flowers. The aim of this review is to present a brief summary of both standard and new findings obtained from using soilless culture techniques in ornamental plant cultivation, based on a detailed literature review. In the researches reached for this review, *Calendula officinalis* L., *Matthiola incana* L., *Pelargonium zonale* L., *Petunia x hybrita* L., *Pinus pinea*, *Cupressus arizonica, C. sempervirens, Sternbergia lutea*, *Galanthus elwesii* Hook, *Lilium candidum, Limonium sinuatum, Eustoma grandiflorum* (*Lisianthus* russellianus) and *Tulipa gesneriana* species were evaluated as plant material. In the researches evaluated, different ornamental plant species, soilless culture techniques and substrates of soilless culture were examined and important results were obtained. Moreover, in the changing living conditions with COVID-19, people have grown plants in their gardens, balconies, terraces and even living rooms using simple hydroponic systems. Thus, they made the simplest practices of soilless culture and even brought it into their homes. It can be foreseen that the commercial and scientific use of hydroponic culture systems in ornamental plants will continue and rapidly increase.
Keywords: cut flower, hydroponic, ornamental plant, plant growth, soilless culture, substrate.

Resumo

Uso de técnicas de cultivo sem solo em plantas ornamentais: uma revisão

A utilização da cultura sem solo no cultivo de plantas ornamentais vem se difundindo, principalmente na produção de flores de corte. O objetivo desta revisão é apresentar um breve resumo das descobertas padrão e novas obtidas com o uso de técnicas de cultivo sem solo no cultivo de plantas ornamentais, com base em uma revisão detalhada da literatura. Nas pesquisas alcançadas para esta revisão, *Calendula officinalis* L., *Matthiola incana* L., *Pelargonium zonale* L., *Petunia* x *hybrita* L., *Pinus pinea*, *Cupressus arizonica*, *C. sempervirens*, *Sternbergia lutea*, *Galanthus elwesii* Hook, *Lilium candidum*, *Limonium sinuatum*, *Eustoma grandiflorum* (*Lisianthus russellianus*) e *Tulipa gesneriana* foram avaliadas como material vegetal. Nas pesquisas avaliadas, diferentes espécies de plantas ornamentais, técnicas de cultivo sem solo e substratos de cultivo sem solo foram examinados e resultados importantes foram obtidos. Além disso, nas condições de vida em mudança com o COVID-19, as pessoas cultivaram plantas em seus jardins, varandas, terraços e até em salas de estar usando sistemas hidropônicos simples. Assim, fizeram as práticas mais simples da cultura sem solo e até a trouxeram para dentro de suas casas. Pode-se prever que o uso comercial e científico de sistemas de cultivo hidropônico em plantas ornamentais continuará e aumentará rapidamente.
Palavras-chave: flor de corte, hidroponia, planta ornamental,crescimento vegetal, cultivo sem solo, substrato.

Introduction

Ornamental plants are used in home decorations, park and garden arrangements coming into prominence with their leaf and flower beauties, their unique smell and shape, and that relaxed people spiritually. Ornamental plants have been used for aesthetic purposes from beginning of civilization history and uses of today ornamental plants occupy a large place. Ornamental plants are an industry serving as the main source of export materials globally and adds value to the national economy. Due to the increase in the rate of urbanization and the decrease in the amount of green field per capita, the need for ornamental plants has increased in recent years. People who move away from nature and break of the connection with the natural environment are reduced to a minimum level may encounter psychological and physiological disorders. Thanks to the positive development in the ornamental plants sector and the increase in their consumption, the disconnection between human and nature can be reduced.

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Ornamental plants playing an important role in landscape studies are a breath of fresh air for people among the agglomerating structures of big cities.

When the world ornamental plant production is evaluated in 2019, an increase is observed in the export of ornamental plants in parallel with the development in the sector (Table 1). According to Table 1, there has been an increase in the export of ornamental plants every year when compared to the previous year. On the basis of product groups, the export share of cut flowers is quite large. Between the years 2015 and 2019, the highest import was in the live plants group (Table 1).

Table 1. Foreign trade values between 2015 and 2019 by ornamental plant product groups in Turkey (1000 $) (Anonymous, 2021a)

Product groups	2015		2016		2017		2018		2019	
	Export	**Import**	**Export**	**Import**	**Export**	**Import**	**Export**	**Import**	**Export**	**Import**
Flower Bulb	1.576	9.995	1.708	9.093	1.293	6.846	1.744	5.477	1.371	2.701
Live Plants	32.414	58.128	22.924	66.580	24.619	66.500	24.957	45.720	31.145	30.981
Cut Flower	28.301	4.883	27.731	4.129	28.851	3.529	34.155	3.261	35.859	3.959
Plant Leaf Branches etc.	6.628	704	7.102	735	7.221	713	7.820	969	8.203	666
Flower Seed	2.703	6.252	2.915	6.109	2.697	6.694	2.562	5.514	3.828	4.729
Total	71.621	79.962	62.379	86.646	64.682	84.282	71.239	60.941	80.406	43.036

The production amount of ornamental plants in Turkey was stated as 1.718,230.040 in 2019 and 1.658.597.260 in 2020 (Table 2). Cut flowers have the highest share with 60.9% in ornamental plants production in our country; outdoor ornamental plants share the remaining 32%, flower bulbs 4% and indoor ornamental plants 3% (Anonymous, 2020a).

Table 2. Ornamental plants production amounts between the years 2019 and 2020 in Turkey (number) (Anonymous, 2021b)
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Product groups	2019	2020
Outdoor ornamental plants	510.558.039	529.109.699
Cut flowers	1.093.333.943	1.009.613.092
Indoor ornamental plants	51.669.029	48.458.815
Flower bulbs	62.669.029	71.415.654
Total	**1.718.230.040**	**1.658.597.260**

Cut flowers have a great potential and future for production and export if suitable agricultural technologies are applied and demanded species are found in the market. In the ornamental plants agricultural sector, quality parameters such as the flowering time of cut flowers, flower yield per plant, stem length, flower diameter can change depend on production techniques such as growing seasons, varieties, soilless or soil culture systems (Özzambak and Zeybekoğlu, 2004).

Soilless culture (culture) requires maintaining optimal conditions for growth and development, appropriate climate management, and the use of balanced irrigation solutions that meet the mineral requirements of certain crops and varieties. Plant cultivation in soilless cultures is one of the preferred alternatives for the control of soil-borne diseases and plant pests. The use of soilless culture method in greenhouses showed a tendency to spread rapidly in the 1970s. Soilless culture is a agriculture method basically applied in greenhouse cultivation, but has recently been used in open field conditions (Hazar and Baktır, 2013).

Soilless culture technique which is the most intensive production system used in horticultural and ornamental plants has been used for several years in Europe and Mediterranean countries. Horticulture and ornamental plant species such as vegetables (pepper, tomato, lettuce, etc. (Gül, 2012)), cut flowers (chrysanthemum, rose (Hazar and Baktır, 2013)), gerbera (Şirin, 2011), blooming bulbous plants (yellow crocus (*Sternbergia lutea)* (Kahraman, 2014a), lily, tulip), potted ornamental plants (anthurium (Dufour and Guérin, 2005), rubber, cyclamen, etc.) were grown in the soilless culture system (Hazar and Baktır, 2013). In recent years, the development of this technique in many developed countries has accelerated due to the greenhouse feature, the development of automation and computer technology. However, in countries with lower technological development, the application of soilless culture is still limited (Olympios, 1999).

The commercial use of soilless culture has been increasing in Turkey in recent years. Many scientific researches have been carried out especially on the production of vegetables and ornamental plants and on soilless culture (Şirin, 2011; Roosta et al., 2016; Khalaj and Noroozisharaf, 2020; Kharrazi et al., 2020). Both in the world and in our country, vegetable cultivation in 92% of soilless agricultural companies are carried out and ornamental plant cultivation is made in the remainder (Özkan, 2020). The use of soilless culture in ornamental plant cultivation is limited, and its use is becoming widespread especially in cut flower production. Soilless culture is used in the cultivation of many cut flower species such as gerbera, tulip, lilium, kala, orchid, lisianthus, anthurium, carnation and chrysanthemum, especially in the cultivation of cut roses.

In recent years, researches on soilless culture have focused on the automation of water and nutrient supply, particularly in closed systems where excess nutrient solution is recycled. Special studies are carried out to develop plant factors based on soilless culture technologies.

The aim of this study is to present a brief summary of both standard and novel findings obtained from using soilless culture techniques in ornamental plant cultivation based on a detailed literature review. It can be foreseen that the commercial and scientific use of soilless culture systems in ornamental plants will continue and rapidly increase.

Soiless Culture Systems and Equipments

Soilless culture systems include aquaculture system with only nutrient solution as root medium and growing in porous growing medium, which creates a matrix capable of holding both air and water in proper proportions for plant growth. Soilless culture systems can be open or closed; in open systems (Figure 1 (a)) the drainage solution is drained while in closed systems (Figure 1 (b)) the drainage solution is collected and reused. Many methods have been tried in soilless culture cultivation in a period of about 80 years. Overall it is a method based on the principle of transporting water and nutrients to the plant's root media to sustain plant life. Therefore, soilless culture techniques used in today is still divided into two groups as basic:

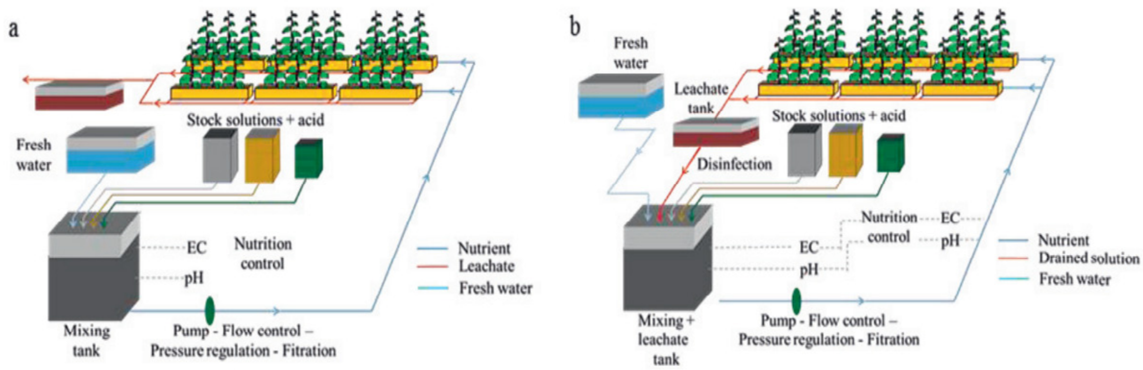

Figure 1. Open system and (a); closed system in soilless culture (b) (Savvas et al., 2013).

Solid Media Culture

It is the most widely used commercially in soilless culture method. It is the environment created by removing the soil from the production environment for various reasons and using various materials besides water. In the solid media culture technique, where the nutrient solution is supplied to the plants through an irrigation system and media culture, the excess solution can be allowed to drain or be recirculated (Gautam et al., 2021).

The functions of solid media used in soilless culture are to provide oxygen to the roots, to dissolved nutrients and bring water into contact with the roots through the medium through the irrigation system, to recirculate the solution within the system by allowing waste to flow, and to stabilize the plants as supportive mediators to prevent them from falling (El-Kazzaz and El-Kazzaz, 2017).

Materials used in growing mediums are divided into organic and inorganic. Organic materials are generally used naturally. These are compost, bark, sawdust, peat, cockpit and other organic wastes (like coconut fiber, peanut shell). Inorganic materials are divided into natural and artificial. Natural solid media can be specified as rock wool, sand, perlite, vermiculite, processed clay, pumice, zeolite, sepiolite and volcanic tuff. Synthetic media are polyurethane, polystyrene, glass wool and styrofoam (Olympios, 1999). In solid media culture, organic and inorganic growing media can be used alone, or they can be mixed in different proportions to complement each other's characteristics to provide a suitable growing environment. These can be formed as perlite-peat or pumice-peat etc.

For an ideal plant cultivation in soilless culture, the physical and chemical properties of the environment should be well known. The water holding capacity of the medium used depends on the size, shape and permeability of its granules. The substrate should have good airspace and good drainage capacity. Therefore, good airspace should be provided around the plant roots. The substrate must be free of harmful or toxic substances. The media to be used in solid media culture should be free from salinity, diseases, pests and weed seeds. The structure of the material used as the solid medium must be slow in the decomposition process (Gautam et al., 2021).

Water Culture

Aquaculture, also known as hydroponic culture, is one of the alternative agriculture methods that helps alleviate the burden on traditional agriculture methods. It is an agricultural system made in the form of contact of plant roots with water containing nutrient solution. Instead of using soil to grow plants, the roots of plants come into direct contact with the nutrient-rich solution. Plants also have easy access to a significant amount of oxygen, which helps facilitate growth in this system. Almost any type of plant can be grown hydroponically, including vegetables, fruits, and flowers. Hydroponics is widely used by growers around the World (Gautam et al., 2021).

Hydroponic technique provides some advantages over soil cultivation for various reasons (Anonymous, 2021c). Since the climatic conditions can be controlled in a greenhouse, plants can be grown throughout the year. In this technique, plants can be grown closer together, as the plant roots do not need to reach the nutrients. Cultivated plants are significantly larger due to the large number of available nutrients and do not have to waste time growing extensive root system. This further increases in the efficiency. At the same time, the nutrient solution always contains the same amount of nutrients in hydroponic technique, while in soil agriculture it tends to "erode" as nutrients are taken up from the soil. The combination of all these advantages causes plants grown in hydroponic technique to be more productive than plants grown in soil. Concern about water use is a major reason why the hydroponic technique is becoming more popular. Hydroponic technique conserves water significantly compared to general cultivation methods. Many growers in various places are starting to switch to hydroponic technique because of all these reasons (El-Kazzaz and El-Kazzaz, 2017).

Plant Nutrition in Soilless Culture Systems

In modern soilless culture systems, all essential plant nutrients are provided through the nutrient solution, with the exception of carbon obtained from the air as carbon dioxide. Most fertilizers used to prepare nutrient solutions are highly soluble inorganic salts. Because of their ability to select nutrients based on their nutrient requirements, different plant species can be successfully grown using a single nutrient solution composition. However, the need to optimize plant nutrition in commercial soilless culture systems has prompted researchers to scrutinize the specific nutritional needs of each plant species grown. Today, special nutrient solution compositions are available for greenhouse-grown plant species (Savvas et al., 2013).

The nutritional needs of a plant species can also change at different developmental stages (Gianquinto et al., 2013). In commercial soilless culture systems, the nutrient solution composition needs to be adjusted periodically over a harvest period. However, programmed changes in nutrient solution composition may be insufficient in many cases because exact nutrient needs vary from product to product, and a standard composition cannot match all individual products. In commercial practice, this problem can be solved by frequently analyzing the drainage solution samples and adjusting the standard nutrient solution formula according to the analytical results (Gautam et al., 2021).

Irrigation water may contain some macronutrients (Mg^{2+}, Ca^{2+}, SO_4^{2-}), micronutrients (Cu^{2+}, Mn^{2+}, Zn^{2+}, Cl^- and B) and other non-nutritive ions (Na^+, HCO^{3-}) in very high concentrations (Sonneveld and Voogt 2009). These nutrients must be taken into account when calculating the amount of fertilizer needed to prepare a nutrient solution.

Electrical conductivity (EC), an estimate of the total ionic concentration in a nutrient solution, is considered one of the most important nutrient solution properties because a very low value indicates deficiencies in the nutrient supply while a very high value indicates salt. Due to the selectivity in nutrient uptake by plants, EC in the root zone of the crop can reduce or increase in optimal plant growth and yield (Gautam et al., 2021).

The optimal pH in the root zone of hydroponically grown plants varies between 5.5 and 6.5. However, in soilless culture systems, the pH can rise rapidly or fall below the critical value range due to the limited volume of nutrient solution per plant in the root zone. Most plants show growth restrictions when exposed to pH levels above 7 or below 5 (Gautam et al., 2021).

Irrigation Methods in Soilless Culture Systems

Although most growing media have high water holding capacity, the total amount of available water and nutrients in the root zone of plants grown in soilless culture systems is smaller than those grown in soil due to the limited volume of the root zone. Frequent and accurate supply of nutrient solution is necessary to maximize crop productivity (Lieth and Oki, 2008). However, this is not a disadvantage of soilless culture systems since the triggering and termination of the water supply can be controlled fully automatically. In the soilless culture system, irrigation is directly affected by the characteristics of the growing medium, ambient humidity constants, irrigation time and duration, and irrigation programs are made according to these parameters.

In soilless culture systems, sprinkler, surface and subsurface irrigation can be applied to provide nutrient solution to plants. However, in soilless culture systems and especially in the products grown in the substrate, surface and especially drip irrigation systems are dominant as the irrigation method. In drip systems, the nutrient solution is supplied via drippers fixed or placed on the top surface of the growing medium, and excess solution is drained or recirculated. Sprinkler irrigation systems that apply nutrient solution to the upper parts of the plants through sprinklers cause excessive water wastage and fungal attacks due to frequent wetting of the leaves. Therefore, while sprinkler irrigation systems are mainly applied in nurseries, their use in productive hydroponic products is scarce. Subsurface irrigation was also tested experimentally. However, it is rarely applied in commercial crops of vegetables and cut flower crops, as it facilitates salt deposition in the upper part of the root zone (Lieth and Oki, 2008).

The basic principle in the drip irrigation method is to deliver a small amount of irrigation water at frequent intervals to the environment where the plant roots develop, with the help of a pressurized pipe and drippers, without creating a tension in the plant caused by the lack of moisture (Anonymous, 2021d). In this method, sometimes watering can be done every day or even more than once a day. In the drip irrigation method, the purified water is conveyed to the drippers placed near the plant through a pressurized pipe network and is delivered to the soil surface under low pressure from the drippers. Water enters the soil by infiltration from here. With the effect of gravity and capillary forces, the soil volume where plant roots develop is wetted. In this method, the entire area is usually not wetted. A wet strip is obtained along the row of plants, leaving an unwetted dry area between the rows of plants. Thus, it is aimed to utilize the existing irrigation water at the highest level.

Irrigation in the form of feeding the nutrient solution to the growing medium from the bottom is called bottom irrigation or capillary system. Capillary systems are systems in which the nutrient solution is applied to the root zone of the plant from below, rises with capillarity in the medium and no waste solution is formed. The working principle of the system is based on the application of the solution taken with the help of capillary pipes from the bottom of the plant root zone (from the bottom of the pot) by passing the relevant nutrient solution through the filter. For this purpose, special float-based valves placed on the bottom of the pot are used under the root zone of the plant. Damage to sensitive leafy plants is prevented in the capillary irrigation system. Since the system is in direct contact with the roots, plant growth and development occur in a controlled and regular manner (Gautam et al., 2021).

Usage of Soilless Culture Techniques in Ornamental Plants

Soilless culture systems are growing rapidly and offer a sector with unlimited potential for the horticultural industry. These systems, which use resources efficiently and are environmentally friendly, are indispensable tools for sustainable production. More researches on these topics will increase in the next few years and will accompany us for decades to come. Crops with less than 10 plants per m^2, such as roses and gerberas, are now grown in fully closed growing systems. Numerous experiments are still being conducted on the cultivation of crops such as freesia, amaryllis and chrysanthemums in soilless culture systems (Kromwijk and van Os, 2020). In this section, results of scientific researches on the use of soilless culture systems in ornamental plants are summarized.

Khalaj and Noroozharaf (2020) investigated the effects of different NO_3^-:NH_4+ ratios on the growth characteristics and macronutrient content of two cut gerbera (*Gerbera jamesonii* Bolus ex Hooker f.) cultivars in an open hydroponic system. Application of NO_3^- and NH_4^+ at a ratio of 40:60 caused a decrease in flower height, stem and disc diameter, flower number, fresh and dry weight of inflorescences, and vase life. According to the present study, gerbera could not tolerate more than 40% of N in the NH_4+ form. P, N and NH_4 + concentrations increased in the leaves of gerbera cultivars with the increase of NH4+ ratio. It has been determined that the optimal ratio determined as NO_3^{-}:NH_4 + 80:20 can be used for gerbera production.

Dufour and Guérin (2005) have conducted research to determine the effects of nutrient solutions with different total N, K and Ca concentrations and different NH4 +/ NO3 ratios on the growth and yield of anthurium plants. According to the results of this research, more than 60% of the applied nutrients were lost in the leachate. As a result of the research, 8.9 mmol N/l nutrient solution concentration was found to be sufficient for a good flower quality and yield for anthurium.

The study was carried out to determine the effects of different nutrient solution recipes on the development of *Leucojum aestivum* L. using the perlite bag culture soilless culture method by Kahraman and Akçal (2018). Four different nutrient solutions were applied to the plants. The highest bulb diameter was observed in NS 200% NPK and NS 125% NPK nutrient solution groups. It has been stated that the recipes created in the form of NS 175% NPK and NS 200% NPK nutrient solution can be used in bulb cultivation of *Leucojum aestivum* L. in order to have high root growth performance and greater bulb size.

As a result of the research conducted by Kahraman and Özzambak (2006), the highest bulb, bulblet and plant growth characteristics were obtained from the sand growing medium by growing *Fritillaria imperialis* in greenhouse conditions using soilless culture method. Sand has been suggested as a medium in soilless culture for the cultivation of *Fritillaria imperialis*.

Al-Ajlouni et al. (2017) aimed to evaluate the effect of different doses of nutrients on growth and flower quality of *Lilium × elegans* Thunb. cv. 'Fangio' under soilless culture application. As nutrient treatment increased in leaf area, substrate EC, chlorophyll content index (SPAD) and number of flowers per plant were increased when compared to control. In general, it was concluded that weekly nutrient application was effective in maintaining yield and flower quality in 'Fangio' lily. It has been concluded that fertigation can be met positively with programs in which fertigation is applied more frequently and the total nutrient level applied is higher.

In order to select the most suitable system for the cultivation of gerbera seedlings, the plants were grown in an integrated bedding system in the form of a closed system containing different culture media (perlite, rock wool, vermiculite, coconut: perlite, vermiculite: perlite) after the acclimatization. The best performances of the plants were determined in vermiculite culture medium, but since there is no significant difference between vermiculite and vermiculite: perlite, it is recommended to use vermiculite: perlite culture medium in a closed system in order to reduce the production costs of gerbera plants (Kharrazi et al., 2020).

Hazar and Baktır (2013) prepared a detailed review about the growing mediums used in soilless culture, the technical details of the system, and the developments in soilless culture for cut rose production in the world and in

Turkey. Accordingly, it has been emphasized that modern soilless culture rose enterprises produce roses with higher yield and quality, and cause less environmental pollution with semi-closed drainage systems, as they can produce more controlled production compared to enterprises operating with primitive methods.

Soilless culture is the most intensive culture system that uses all resources efficiently for optimum crop yield and the most intensive horticultural plants for commercial production in the greenhouse (Khalaj and Noroozisharaf, 2020). It is vital to identify and further develop sustainable materials, technologies and approaches while keeping energy and production costs low and transport distances short in soilless culture systems. There are many studies on different substrates that were used and can be used in this context. Commercial growers of potted ornamentals almost exclusively use soilless culture media as a substrate for growing plants (Leiva et al., 2019). The advantages of a soilless medium are that it consists of organic materials, and that a significant amount of pesticides can leach from pots containing soilless medium to which pesticides are added by spraying or as top dressing. The research abstracts substrates examined usage status in ornamental plant cultivation under soilless culture conditions were examined below.

In a study conducted Chrysargyris et al. by (2018), the use of olive seed (ZCA) and paper waste (CA) as a growing medium at different rates in ornamental plants cultivation as a peat (T) substitute was investigated. Plants of petunia (*Petuni*a x hybrita L.), calendula (*Calendula officinalis* L.), matthiola (*Matthiola incana* L.) were grown in the growing media of the application groups formed as 1) T (100%), (2) T:ZCA (90%:10%), (3) T:ZCA (70%:30%) and (4) T:ZCA:KA (60%:20%:20%). Addition of 10%-30% olive seed powder to solid medium increased in calendula height when compared to calendula plants grown in 100% peat medium. No significant differences were detected in plant size (pot filling volume), dry matter content and plant biomass. Petunia size, and flower earliness (blooming), total number of flowers were found to increase in the presence of ZCA when compared to plants grown in 100% peat. In this study, it was concluded that up to 30% of ZCA could be an alternative to peat in the cultivation of calendula and petunia flowers. While it has been determined that only up to 10% of ZCA can be used for matthiola, it is not recommended to add paper waste on top of ZCA.

In another study examining the use of paper wastes, which occur in significant amounts in the paper industry, as a growing medium for potted ornamental plants, For the preparation of potting soil for matthiola (*Matthiola incana*), petunia (*Petunia* x *hybrida* L.) and calendula (*Calendula officinalis* L.) plants, waste paper (0%, 10%, 30%, 50%, 100% on a volume basis) was added to the peat medium at different rates. Addition of waste paper increased in the pH and mineral content of the solid medium, but decreased in the aeration capacity of the medium. In this study, it was reported that the physicochemical properties of the substrate should be further improved, and that up to 30% of the waste paper added to the peat can be substituted for the pot medium in calendula and petunia cultivation. However, it has argued that it cannot be substituted for the matthiola (Chrysargyris et al., 2019).

As substitutes for peat material, use in the production of green waste compost (GWC) and green waste worm compost (GWV) in calendula (*Calendula officinalis* L.) and geranium (*Pelargonium zonale* L.) cultivation has been evaluated (Gong et al., 2018). It has been stated that 50%-100% of the peat used for potted production of geranium and calendula can be substituted with GWV.

The study tested the performance of the aphid *Rhodobium porosum* (Hemiptera: Aphididae) on three rose cultivars exposed to two nutrient solutions in subsurface 'ebb and flow' irrigation systems in greenhouse. The performance of *R. porosum* was determined by means of the life table and fertility. Both cultivar and fertilization affected many life history and population traits of the aphid. The lowest performance of the *R. porosum* was found on 'Tineke' rose cultivar cultivated in the nutrient solution 1, that usually recommended for fruit-type vegetables. The result of research has shown that 'Tineke' rose cultivar cultivated in the nutrient solution 1 was be the best combination to use to reduce problems with aphid attack in soilless rose cultivation (Avellar et al., 2021).

This research was conducted by Leiva et al. (2019) to determine whether individual components containing soilless media have different affinities for the pesticide acephate, metalaxyl, imidacloprid and the paclobutrazol. The results showed significant differences in pesticide behavior with each substrate (sand, vermiculite, perlite, coconut, pine bark, peat). It has been emphasized that the absorption properties of soilless media components can be highly variable depending on the chemical and substrate component.

The use of different waste materials such as pine bark, coconut fiber and sewage sludge as substrate in the production of ornamental plants, especially the suitability of coconut fiber as a growing substrate for conifers has been studied. *Cupressus arizonica, Cupressus sempervirens and Pinus pinea* were used as plant material in the study. The mixture between pine bark or coconut fiber and 30% biosolid compost by volume was produced the best results for *Cupressus arizonica* and *Cupressus sempervirens* (Hernández-Apaolaza et al., 2005).

In the study conducted by Dubey et al. (2013), the most ideal potting medium that can be used in potted petunia cultivation was investigated by using different media components including leaf manure, sewage sludge, vermicompost, farm manure, coconut peat and soil. Based on the results obtained, it was concluded that the media composition of soil + sewage sludge (2:1) was the best potting medium for growing petunia plants.

Five types of substrates formed as pH 4.0 peat, pH 5.5 peat, 100% Perlite, 50% Perlite + 50% pH 4.0 peat and 50% Perlite + 50% pH 5.5 peat were used in gerbera cultivation. The highest values in terms of number of flowers, flower size, flower diameter and shoot diameter were obtained from the application using 50% Perlite + 50% peat substrate in pH 5.5. (Drăghici et al., 2020).

Perlite, coconut fiber and zeolite were used as growing media in the research conducted to determine the effect of different growing media on the growth and development of *Sternbergia lutea* bulbs under soilless culture conditions. It has been determined that coconut fiber can be used as a medium in soilless cultivation of *Sternbergia lutea* (Kahraman, 2014a).

The effects of different growing media (zeolite, perlite, pumice, peat, sand, sawdust, coconut fiber) on bulb and plant growth of *Galanthus elwesii* Hook were investigated under soilless culture conditions. It has been concluded that coconut fiber and peat can be used as medium in soilless culture conditions to increase in the quality characteristics of *Galanthus elwesii* Hook bulb (Kahraman and Özzambak, 2014).

The effects of different growing media (sand, pumice, perlite, zeolite and coco peat) on plant growth of *Lilium candidum* were investigated in substrat culture-soilless culture method under greenhoses conditions (Kahraman 2014b*).* The highest results in terms of stem length and bulb diameter parameters were obtained from the growing medium in which coconut fiber was used (Kahraman, 2014b).

In the cultivation of two different *Limonium sinuatum* species (Compindi White and Compindi Deep Blue) under greenhouse conditions, the use of peat, perlite, slag media and their mixtures in equal amounts (1:1:1) and soil media were evaluated (Saraçoğlu et al., 2017). In the cultivation of *L. sinuatum* with soilless culture technique, the highest values obtained from terms of plant growth were determined in peat and mixture media.

Domingues Salvador and Minami (2001) investigated the effects on plant growth and flower quality of different substrates (coconut fiber and perlite) used as growing media in lisianthus (*Eustoma grandiflorum* (*Lisianthus russellianus*)) cut flower cultivation. Coconut fiber showed better effect on plant growth and flower quality than perlite medium. As a result of the study, in general, the substrates were found to have similar effects with cultivation in the soil.

Conclusions

In conclusion, a significant portion of the area that can be used as agricultural land in the world includes soils with high salt content, sodic or polluted content, poor soil structure and/or low soil fertility. The main reason for the rapid spread of soilless culture systems all over the world in the last thirty years is that other problems related to soil properties, including soil-borne pathogens, have disappeared. In addition, with the use of these systems, tillage and preparation operations can be ignored since there is no need for herbicides and frequent rotations. This is increased in the length of the potential cultivation period and therefore the yield is increased. On the other hand, soilless culture system can provide better plant growth and earliness for plants, better quality for cut flowers and potted ornamental plants under controlled conditions, and more durable covered seedlings. Other advantages such as better environmental protection with closed recirculation systems and improved product quality with a precise nutrient dosage make soilless culture systems increasingly important. These systems also need to be implemented more intensively to support eco-culture in the ornamental plants sector. In line with all these advantages, we believe that soilless culture systems will continue to be used in the cultivation of ornamental plants and will increase in rapidly.

Author Contribution

FPK: Creation idea, preparation of the manuscript, research orientation, suggestions and ideas. **AD**: Preparation of the manuscript. **MK:** Collect of data, preparation of the manuscript.

References

AL-AJLOUNİ, M.G.; AYAD, J.Y.; OTHMAN, Y.A. Increasing nutrient levels promote growth and flower quality in lilies grown under soilless culture. **Horticultural Science,** v.44, n.4, p.171-177, 2017. http://dx.doi.org/10.17221/166/2016-HORTSCI

ANONYMOUS 2021a. **Ornamental plants and products sector report 2020**. Available at: <http://www.susbitkileri.org.tr/images/d/library/f3e9a4f0-abd9-4d63-8f39-e1b5451f5a3d.pdf>. Accessed May 20th 2021.

ANONYMOUS 2021b. **Türkiye İstatistik Kurumu (TÜİK)**. Available at: <https://data.tuik.gov.tr/Bulten/Index?p=Crop-Production-2020-33737>. Accessed May 19th 2021.

ANONYMOUS 2021c. **Hydroponic-systems**. Available at: <http://www.homehydrosystems.com/hydroponic-systems/aeroponics_systems.html>. Accessed Jun 17th 2021.

ANONYMOUS 2021d. Available at: <https://www.netafim.com.tr/akademi/toprak-alti-damla-sulama-kurulumu/>. Accessed Jun 23th 2021.

AVELLAR, G.S.; CAMPOS, W.G.; CARVALHO, L.M.; ALMEİDA, E.F.; RİBEİRO, M.N. Life Table of *Rhodobium porosum* on Rose Cultivars in Subsurface'Ebb and Flow'Irrigation System. **Life,** v.33, n.7, 2021. http://dx.doi.org/10.9734/IJPSS/2021/v33i1730550

CHRYSARGYRIS, A.; ANTONIOU, O.; TZIONIS, A.; PRASAD, M.; TZORTZAKIS, N. Alternative soilless media using olive-mill and paper waste for growing ornamental plants. **Environmental Science and Pollution Research,** v.25, n.36, p.35915-35927, 2018. http://dx.doi.org/10.1007/s11356-017-1187-4

CHRYSARGYRIS, A.; STAVRINIDES, M.; MOUSTAKAS, K.; TZORTZAKIS, N. Utilization of paper waste as growing media for potted ornamental plants. **Clean Technologies and Environmental Policy**, v.21, n.10, 1937-1948, 2019. http://dx.doi.org/10.1007/s10098-018-1647-7

DOMİNGUES SALVADOR, E.; MİNAMİ, K. Evaluation of different substrates on Lisianthus (*Eustoma grandiflorum* Shinn) growth. **International Symposium on Growing Media and Hydroponics,** 644, p.217-223, 2001. http://dx.doi.org/10.17660/ActaHortic.2004.644.29

DRĂGHİCİ, D.E.; PETRA, S.; TOMA, F.; JERCA, O.I. The influence of substrate type on growth and flowering of gerbera plants. **Scientific Papers-Series B, Horticulture**, v.64, n.1, p.569-577, 2020.

DUBEY, R.K.; SIMRAT-SINGH, KUKAL, S.S.; KALSI, H.S. Evaluation of different organic growing media for growth and flowering of petunia. **Communications in Soil Science and Plant Analysis**, v.44, n.12, p.1777-1785, 2013. http://dx.doi.org/10.1080/00103624.2013.790398

DUFOUR, L.; GUÉRIN, V. Nutrient solution effects on the development and yield of *Anthurium andreanum* Lind. in tropical soilless conditions. **Scientia Horticulturae**, v.105, n.2, p.269-282, 2005. http://dx.doi.org/10.1016/j.scienta.2005.01.022

EL-KAZZAZ, K.A.; EL-KAZZAZ, A.A. Soilless agriculture a new and advanced method for agriculture development: an introduction. **Agricultural Research & Technology: Open Access Journal**, v.3, p.63-72, 2017. http://dx.doi.org/10.19080/ARTOAJ.2017.03.555610

GAUTAM, R.; SINGH, P.K.; KUMAR, P.; SINGH, M.; DHITAL, S.; RANI, M.; SHARMA, V.K.; JNAPIKA, K.H.; KUMAR, J. Advances in soilless cultivation technology of horticultural crops. **The Indian Journal of Agricultural Sciences,** v.91, n.4, p. 11-16, 2021.

GIANQUINTO, G.P.; MUÑOZ, P.; PARDOSSI, A.; RAMAZZOTTI, S.; SAVVAS, D. Soil fertility and plant nutrition. In: **Good Agricultural Practices for Greenhouse Vegetable Crops – Principles for Mediterranean Climate Areas**. Plant Production and Protection Paper v.217. Rome: FAO, 2013. p.205-269,

GONG, X.; LI, S.; SUN, X.; WANG, L.; CAI, L.; ZHANG, J.; WEI, L. Green waste compost and vermicompost as peat substitutes in growing media for geranium (*Pelargonium zonale* L.) and calendula (*Calendula officinalis* L.). **Scientia Horticulturae,** v.236, p.186-191, 2018. http://dx.doi.org/10.1016/j.scienta.2018.03.051

HAZAR, D.; BAKTIR, İ. The cultivation of roses on soilless culture. **International Journal of Natural and Applied Sciences**, Special Issue, v.17, n.2, p.21-28, 2013.

HERNÁNDEZ-APAOLAZA, L.; GASCÓ, A.M.; GASCÓ, J.M.; GUERRERO, F. Reuse of waste materials as growing media for ornamental plants. **Bioresource Technology,** v.96*,* n.1, p.125-131, 2005. http://dx.doi.org/10.1016/j.biortech.2004.02.028

KAHRAMAN, Ö. Bulb enlargement of *Sternbergia lutea* using soilless culture method. **COMU Journal of Agriculture Faculty,** v.2, n.2, p.35–39, 2014a.

KAHRAMAN, Ö. The effects of different substrates on *Lilium candidum* cultivation under greenhouse condition. **Journal of Agricultural Faculty of Gaziosmanpasa University,** v.31*,* n.3, p.68-72, 2014b.

KAHRAMAN, Ö.; AKÇAL, A. Yhe effects of diffirent nutrient solutions on summer snowflake's development in soilless culture. **COMU Journal of Agriculture Faculty,** v.6, p.169-176, 2018.

KAHRAMAN, Ö.; ÖZZAMBAK, E. Effects of organic and inorganic substrates on bulbs of Fritillaria imperialis in soilless culture, greenhouse condition. **Journal of Scıence**, v.6, n.2, p.65-70, 2006.

KAHRAMAN, Ö.; ÖZZAMBAK, M.E. The effects of different media on *Galanthus elwesii* Hook bulb performance in soilless culture. **Afyon Kocatepe University Journal of Science & Engineering**, v.14*,* n.1, 2014.

KHALAJ, M.A.; NOROOZİSHARAF, A. Efficiency of ammonium and nitrate ratios on macronutrient content and morphological properties of *Gerbera jamesonii* cut flower. **Agriculturae Conspectus Scientificus**, v.85, n.3, p.281-289, 2020.

KHARRAZİ, M.; SHARİFİ, A.; NEJATİZADEH, S.; KHADEM, A.; MORADİAN, M. Selection of optimal cultivation media for gerbera (*Gerbera Jamesonii*) growth in the hydroponic culture system. **Journal of Horticultural Science**, v.34, n.2, p.261-271, 2020. doi.org//10.22067/jhorts4.v34i2.79193

KROMWİJK, J.A.M.; VANOS, E.A. Advances in soilless culture of ornamentals. In: GRUDA N.S. (Ed.). **Advances in horticultural soilless culture**. Cambridge: Burleigh Dodds Science Publishing Limited, 2020. 442p.

LEIVA, J.A.; WILSON, P.C.; ALBANO, J.P.; NKEDI-KIZZA, P.; O'CONNOR, G.A. Pesticide sorption to soilless media components used for ornamental plant production and aluminum water treatment residuals. **ACS omega,** v.4*,* n.18, p.17782-17790, 2019. http://dx.doi.org/10.1021/acsomega.9b02296

LIETH, J.H.; OKI, L.R. Irrigation in soilless production. In: RAVİV, M.; LİETH, H.J. (eds.). **Soilless Culture: Theory and Practice**. Amsterdam: Elsevier, 2008. p.117-156.

OLYMPIOS, C.M. Overview of soilless culture: advantages, constraints and perspectives for its use in Mediterranean Countries. **Cahiers Options Mediterraeennes**, v.31, p.307-324, 1999.

ÖZKAN, C.F. An alternative solution to increasing population needs and soil problems: soilless agriculture. **Turkish Journal of Agriculture and Forestry,** January-February 2020, Interview.

ÖZZAMBAK, E.; ZEYBEKOĞLU, E. Soilless gerbera cultivation in greenhouse and comparison of some growing media**. Izmir Chamber of Commerce Publication**, n.140, İzmir, (in Turkish), 2004.

ROOSTA, H.R.; MANZARI TAVAKKOLI, M.; HAMIDPOUR, M. Comparison of different soilless media for growing gerbera under alkalinity stress condition. **Journal of Plant Nutrition**, v.39, n.8, p.1063-1073, 2016. http://dx.doi.org/10.1080/01904167.2015.1109112

SARAÇOĞLU, Ö.A.; AKAT, H.; GÜNEŞ, A.; ÇAKAR, H.; KILIÇ, C.C. Effects of different growing media on the growth and yield in cultivar of *Limonium sinuatum* 'Compindi White' and 'Compindi Deep Blue'. **Journal of Ege University Faculty of Agriculture**, v.54, n.2, p.187-195, 2017.

SAVVAS, D.; GIANQUINTO, G.P.; TÜZEL, Y.; GRUDA, N. Soilless culture. In: FAO. **Good agricultural practices for greenhouse vegetable crops – principles for mediterranean climate areas**. Plant Production and Protection Paper, v.217. Rome: FAO, 2013. p.303–354.

SONNEVELD, C.; VOOGT, W. **Plant nutrition of greenhouse crops**. Dordrecht, Heidelberg, London, New York: Springer,), 2009. 431 p.

ŞİRİN, U. Effects of different nutrient solution formulations on yield and cut flower quality of gerbera (*Gerbera jamesonii*) grown in soilless culture system. **African Journal of Agricultural Research**, v.6, n.21, p.4910-4919, 2011. http://dx.doi.org/10.5897/AJAR11.578