Turkish Journal of Agriculture - Food Science and Technology, 12(10): 1772-1778, 2024
DOI: https://doi.org/10.24925/turjaf.v12i10.1772-1778.7126

Turkish Journal of Agriculture - Food Science and Technology

Available online, ISSN: 2148-127X | www.agrifoodscience.com | Turkish Science and Technology Publishing (TURSTEP)

Investigation of Rooting Performance of Some Grapevine Rootstocks with Aeroponic Method

Deniz İpek[1,a], Hakan Karadağ[1,b,*]

[1]*Tokat Gaziosmanpasa University, Faculty of Agriculture Department of Horticulture 60100, Tokat, Türkiye*
[*]*Corresponding author*

A R T I C L E I N F O

Research Article

Received : 12.09.2024
Accepted : 27.09.2024

Keywords:
Aeroponic
Rootstock rooting
IBA
Vine rootstocks
Soilless agriculture

A B S T R A C T

In the study, the aeroponic system examined the rooting performances of three grapevine rootstocks (110R, 1103 Paulsen, 5BB) commonly used in Türkiye. IBA was applied to grapevine cuttings to encourage rooting. Grapevine cuttings taken during the winter dormancy period were placed in the aeroponic system after the necessary pretreatments. Significant improvements were observed in root length, root number, and rooting rate during the rooting process of cuttings placed in the aeroponic system. No diseases or pests were observed during the rooting period in the daily checks. As a result of the study, the highest root length was 17.77 cm in 110R rootstock, while the lowest was 7.1 cm in 1103P rootstock. The highest rooting rate was 76.67% in a 25 ppm IBA application in 1103P rootstock and 73.33% in a 100 ppm IBA application. The lowest rooting was 10% in 110R rootstock at 100 ppm IBA application dose and in the control group. The study's results revealed the positive effects of aeroponic systems in increasing rooting performance. The advantages offered by these systems are essential in terms of sustainability and efficiency in agriculture. Considering global challenges such as climate change and the reduction of agricultural areas, aeroponic systems are expected to find wider applications in the future.

[a] *denizipek@hotmail.com* *https://orcid.org/0009-0008-4076-7050* | [b] *hakan.karadag@gop.edu.tr* *https://orcid.org/0000-0002-1458-7645*

This work is licensed under Creative Commons Attribution 4.0 International License

Introduction

Turkiye ranks 5th in vineyard area, with a production area of approximately 400,000 hectares, after Spain, China, France, and Italy (Anonymous, 2023). The development of the viticulture and nursery sector in Turkiye, which has increased by 40% in the last twenty years (FUAB, 2022), also causes an increase in the demand for materials used in the nursery sector. There are problems in producing these materials due to soil degradation, soil-borne diseases, high production costs, and insufficient irrigation water. The supply problems experienced in production materials, significantly increasing production costs, put producers in a difficult situation. Due to the increasing production, there is also a significant supply problem in our country regarding rootstocks.

Despite Turkiye's genetic resources and production potential, much of its soil is infected with the phylloxera pest (Çelik, 2012). This situation requires viticulture to be carried out using grafted grapevine saplings in the country. In addition to soil and environmental conditions, the selected rootstock also plays an essential role in grapevine cultivation (Gargın et al., 2011). In Turkiye, many rootstocks are used that can adapt to different soil types, have different resistance to drought, lime, salinity, phylloxera, and nematodes, and have different compatibility with V. vinifera varieties (Yağcı & Erdem, 2019).

The need for alternative production models to eliminate rootstock supply problems is increasing. For this purpose, soilless agriculture methods come to the fore. Soilless agriculture includes various innovative techniques, such as hydroponics and aeroponics, which recently attracted significant attention (Lakhiar et al., 2018). These methods include growing plants without soil using nutrient-rich solutions or misty environments to provide the necessary elements for plant growth (Rani et al., 2022; Şimşek & Gül, 2018). The aeroponic farming system, the most widely used soilless farming system today, is the focus of our study. Lakhiar et al. (2020) revealed in their research that the aeroponic system is one of the revolutionary and more sustainable methods of the soilless system, as it reduces water requirements and provides significant space and soil savings. Research on the aeroponic system began in the first quarter of the 20th century, and in the 1990s, NASA proved that the method was very efficient in its studies on growing plants in space and on Earth without soil and with very little water (Kumari & Kumar, 2019).

Plants are in the air support system in the aeroponic system; nutrients are sprayed to the root zone as water vapor. In particular, recycling and reusing irrigation water provides significant water and nutrient savings. (Lakhiar et al, 2020). Rajan and Sravani (2021) state that plants grow and develop faster since the roots have full access to oxygen and carbon dioxide concentrations.

There is no habitat for soil-borne diseases and pests. Due to the humid environment, the system is disinfected at specific periods against developing fungal diseases. Cultivation occurs in a closed and controlled environment, making product harvesting labor easy (Sahoo, 2020). Aeroponically formed roots are advantageous in terms of optimum lateral rooting and abundant capillary root formation compared to roots formed in soil. In addition, this approach provides the advantage of easy access to the root system (Peterson & Krueger, 1988). It should not be forgotten that cuttings enslaved in aeroponics require intensive irrigation in the first stages when they are taken to the acclimation environment.

Smart sensor techniques and IoT platforms can further improve these systems, allowing precise control of environmental factors such as microclimate and nutrient management (Sagheer et al., 2020; Roffi & Jamhari, 2023). The adoption of soilless cultivation systems has been particularly prominent in Mediterranean greenhouses, where closed systems have proven to be more efficient in terms of ecological factors than open systems (Sharma et al., 2022). It is considered a potential solution for global food security, especially in urban agriculture and the COVID-19 pandemic (Pulighe & Lupia, 2020). Urban farming has received increasing attention due to its potential to solve problems such as food insecurity, depression, and anxiety and its role in providing fresh produce in densely populated areas (Misganaw, 2021). In addition, integrating soilless systems into urban environments has been emphasized as a way to combine agriculture and architecture, offering a synthesis that addresses the challenges of urban growth (Marcynuk, 2011).

The aeroponic system is the best plant-growing technology in many ways compared to different growing systems. The system is rapidly gaining momentum and increasing popularity and is the fastest-growing modern agricultural sector. It can be used effectively to produce vegetables, saplings, etc., in various countries with insufficient natural resources.

Turkiye is located in the Middle East, a region where water resources are scarce. In their research, Aküzüm et al. (2019) revealed the water losses caused by agricultural production and irrigation-related problems. They revealed the importance of controlled water use in protecting our country's sustainable resources. Significant water savings are achieved since the water given as a spray in the aeroponic system is reused.

In this study, the rooting performances of 110R, 1103P, and 5BB rootstocks, which are widely used in Turkey and the world in grapevine sapling production, were investigated in the aeroponic system. The aim of the study is to reveal the possibilities of using the aeroponic method, which is increasingly used commercially, in grapevine rootstock rooting.

Materials and Methods

Plant Material

In the study, 110R, 1103Paulsen, and 5BB grapevine rootstocks, widely used in Turkiye and known to be the most resistant to phylloxera, were used as plant material. 110 R rootstock is a rootstock that is very resistant to active lime up to 17% and drought. Its rooting ability is very weak. 1103 Paulsen rootstock is also well adapted to humid and clayey-calcareous soils and is resistant to active lime around 17-18%. 5BB rootstock is a strong rootstock resistant to active lime and nematodes by around 20%. (Yağcı and Erdem 2019). 110R, 1103 Paulsen, and 5BB Grapevine Rootstocks to be used in the study were supplied by a private company producing in Tokat province.

Rootstocks cut from the field were delivered to the Aeroponic rooting unit established in the greenhouse of Tokat Gaziosmanpaşa University Agricultural Research and Application Center. Rootstocks delivered to the rooting unit were pre-washed, cleaned of foreign materials, and prepared for planting.

IBA Application

The IBA application was done using a slow immersion method. Cuttings were kept in an IBA solution prepared using 0-25-50-100 ppm doses (95 ml pure water + 5 ml ethyl alcohol) in a dark environment at +4°C for 24 hours and then taken into the system (Demirbaş, 2019; Anonymous, 2022). Wood cuttings were used in the trial and were placed in the system in January (Figure 2).

Trial Plan

The study examined the rooting performances of three different grapevine rootstocks in 4 different IBA doses in an aeroponic environment. For this purpose, the study was designed with three replications and ten cuttings in each replication. The placement of the rootstocks on the cabin was distributed randomly. Statistical analysis of the obtained data was done with the SAS Package program.

Aeroponic Rooting System

Our study used the Aeroponic Rooting system installed in the greenhouse at the Tokat Gaziosmanpaşa University Agricultural Research and Application Center.

The aeroponic rooting unit is manufactured from metal cabins and is based on spraying water and nutrient solution to the roots. There is a bottom heating system in the cabins, and temperature and humidity controls are done with the help of sensors. The cabin's interior is kept at a constant temperature between 22-24 0C with heating pads. The depth of the cases is 40 cm, and the distance between the floors is designed as 50 cm (Figure 1).

A timer was used to water the rootstocks used in the study. In order to moisten the lower parts, water was given by misting for 20 seconds at 20-minute intervals. In the upper parts, due to winter conditions and the plants losing less water, moisturizing was done for 10 seconds at 40-minute intervals (Figure 3).

Results

Within the scope of the study, the rooting performances of three grapevine rootstocks used extensively in Turkiye were examined in the aeroponic system. Cuttings taken during the winter dormancy period were placed in the system after pretreatment and their rooting performances were examined.

The disease formation and moisture status of the cuttings placed in the system were checked daily and routinely. No disease or pest was observed during the rooting phase. No drug use was required within the scope of the study.

Rooting Rates

When rooting rates are examined statistically, it is seen that there are Significant differences between them (Graph 1). The highest rooting rate was 76.67% in 1103P rootstock with 25 ppm IBA application, while the lowest rooting rates were observed as 10% in 110R rootstock with control and 100 ppm IBA application doses. Some studies have also stated that the rooting rate of 110R rootstock is relatively low (Table 1).

Number of Roots

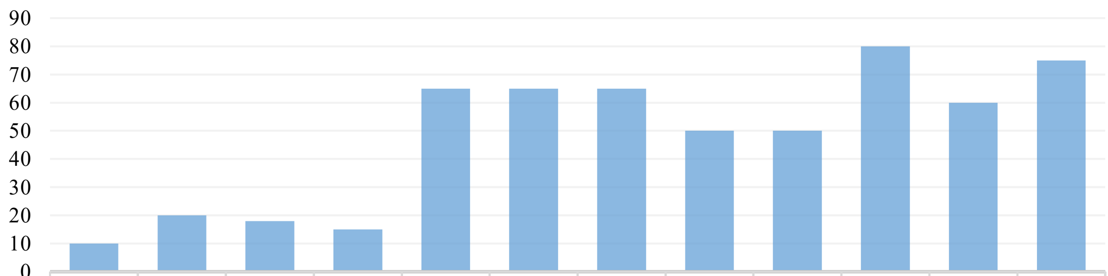
As a result of the analysis, statistically significant differences were found in terms of root number. The highest root number was observed with 9.567 in 5BB rootstock at 25 ppm IBA application dose, while the lowest root number was observed with 2.670 in 110R rootstock at 100 ppm IBA application dose (Table 2).

Figure 1. Aeroponic rooting system (Original)

Figure 2. IBA Application and placement of cuttings in the system (Original)

Figure 3. Examination of cuttings during the rooting process

Rooting rate (% avg)



	110 R Kont 110R	110R 25 ppm 110R	110R 50 ppm 110R	110R 100 ppm 110R	55S Kont 55S	55S 25 ppm 55S	55S 50 ppm 55S	55S 100 ppm 55S	1103P Kont 1103P	1103P 25 ppm 1103P	1103P 50 ppm 1103P	1103P 100 ppm 1103P
Rooting rate (%)	10	20	18	15	65	65	65	50	50	80	60	75

Graph 1. Cutting rooting rates (% average)

Table 1. Statistical analysis of rooting rate

Rooting rate	Rootstocks		
IBA Doses	110R	5BB	1103P
Control	10.00 c	63.33 ab	46.67 abc
25 ppm	20.00 bc	63.33 ab	76.67 a
50 ppm	16.67 bc	63.33 ab	50.00 abc
100 ppm	10.00 c	50.00 abc	73.33 a

Table 2. Statistical analysis of root number

Number of roots	Rootstocks		
IBA Doses	110R	5BB	1103P
Control	3.500 cd	9.567 a	8.617 ab
25 ppm	4.223 bcd	9.623 a	9.477 a
50 ppm	3.585 cd	8.523 ab	9.113 a
100 ppm	2.670 cd	8.200 abc	7.910 abc

Table 3. Root diameter statistical analysis

Root diameter	Rootstocks		
IBA Doses	110R	5BB	1103P
Control	0.7206a	0.5333 a	0.7667 a
25 ppm	0.8500 a	0.7200 a	0.6133 a
50 ppm	0.6980 a	0.5612 a	0.5000 a
100 ppm	0.9800 a	0.9714 a	0.4600 a

Table 4. Root length statistical analysis

Root length	Rootstocks		
IBA Doses	110R	5BB	1103P
Control	12.781 b	9.240 bcde	7.580 cde
25 ppm	12.380 bc	7.330 de	9.937 bcde
50 ppm	9.490 bcde	8.057 bcde	8.653 bcde
100 ppm	17.770 a	12.215 bcd	7.097 e

Root Diameter

There is no statistically significant difference in root diameter in the analysis results. The highest root diameter was observed in the 110R rootstock with a value of 0.98 at 100 ppm IBA application dose (Table 3).

Root Length

As a result of the analysis, statistically significant differences were observed between root lengths in terms of applications. The longest root formation was observed in 110R rootstock in 100ppm IBA application, while the shortest was in 1103P rootstock in 100ppm IBA application (Table 4).

As a result of the findings obtained, no significant difference was observed in root diameters and maintenance in the analyses performed.

On average, the highest fresh root weight was observed in 1103P rootstock in 25ppm IBA application, while the lowest fresh root weight was observed in 110R Control rootstock. On average, the highest root dry weight was observed in 5BB rootstock in the control application, while the lowest root dry weight was observed in 110R Control rootstock.

As a result of observations made on the upper parts of the cuttings, no statistical differences were found in terms of shoot length, shoot number, and leaf number. The longest shoot development was observed in the 1103P variety with 50 ppm IBA application, while the shortest shoot development was observed in the 110R variety with 25 ppm IBA application. The highest leaf number was observed in 1103P rootstock with 25 ppm IBA application with a ratio of 6.967, while the lowest leaf number was observed in 5BB control application with a ratio of 4.073.

Discussion

Soilless farming systems offer many advantages compared to traditional soil-based farming methods and provide significant yield increases, especially in the rooting processes.

In the literature research, few studies have been reached on the rooting of grapevine rootstocks in aeroponic environments. It is seen that mostly green annual plants are grown in an aeroponic environment. Generally, higher successes have been achieved in rooting studies compared to classical methods. Another advantage of the aeroponic method is that rapid rooting is emphasized in the literature.

Armi et al. (2023) conducted a study on lettuce using hydroponic and aeroponic systems and found that both systems affected growth parameters and also increased yield and quality parameters in lettuce. Kratsch et al. (2006) periodically sprayed the roots with a nutrient solution using extra fine mist nozzles controlled by a timer to maintain the plants' controlled root zone atmosphere. A study on the effects of O2 on root nodule formation reported that 100% of the plants survived after four weeks and that abundant nodulation occurred. Baciu et al. (2023) stated that vertical farming techniques can be applied to mulberry cultivation in a controlled environment and that the aeroponic system can be adapted to a wider range of functional plants, especially mulberry. AeroFarms has established the world's largest indoor vertical farm at its facility in New Jersey. With this technology, the farm has the capacity to produce and sell up to two million pounds of pesticide-free leafy greens per year (Anonymous, 2023).

In the Netherlands, aeroponic systems used in commercial greenhouses have been shown to increase the yields of high-value crops such as tomatoes and cucumbers by up to 30%. It has also been noted that these systems offer a sustainable production method by reducing water use by 70%. Similarly, aeroponic systems used in viticulture in the Netherlands have significantly shortened the rooting period and developed healthier and stronger root structures than traditional soil systems (Nederhof et al., 2010). As a result of our study, similar to Nederhof (2010), rapid and effective root formation was observed in grapevine rootstocks.

Aeroponics is a total system that enables plants to grow and develop. It is basically an air-water culture in which nutrients are directly supplied to the bare root system in a water mist. Thus, oxygen and water, which are often limiting growth factors in traditional soil and water media systems, are provided at sufficient levels (Nir, 1982). Researchers have emphasized that high yields per unit area are obtained thanks to the layered system (Gurley, 2020; Rodriguez, 2013). In our study, which presents similar findings to the literature, 300 liters of water were used in the system cycle during the rooting process. At the end of the study, 30% of water loss occurred due to plant use, system leaks, and evaporation.

Various other auxin application methods have been reported to date. It has been stated that there are opportunities for further development of auxin application techniques that can improve plant quality. Callus formation has been stated as an important step in the cutting propagation process. High IBA doses have been shown to increase callus formation, especially in aeroponic systems, and indirectly support rooting. Similarly, studies indicate that high IBA doses positively affect callus formation in aeroponic conditions (Blythe, 2007; Akakpo, 2014).

Regas et al. (2021), in a study on hemp, applied IBA to the basal part of the cuttings before being placed in the system. It was stated that the method described here provides a more effective way for the asexual propagation of hemp by alleviating the potential time constraints arising from traditional methods. In his research, Sukhjit (2015) investigated the rooting of peach wood cuttings (IBA) with different treatments. The basal part of the cuttings was planted in open field conditions with 1000 ppm, 2000 ppm, 3000 ppm, 4000 ppm, and 5000 ppm IBA applied. It was stated that the cuttings treated with 3000 ppm IBA achieved significant success in terms of the highest germination percentage, survival percentage, average root number, main root length, root circumference, root weight, and rooting days.

In a study conducted by Sağlam et al. (2023) to examine the rooting performance of 16 different grapevine rootstocks in perlite medium, the lowest rooting rate was observed in 110R anaconda with 33%. Similarly, in our study, 30% success was achieved in rooting of 110R rootstock. Similarly, high success was achieved in the 5BB and 1103P varieties. Kelen & Demirtaş (2001) In this study conducted at Eğirdir Horticulture Research Institute, different rooting media were used on the rooting and root quality of American grapevine rootstocks 5 BB and 420 A. While 5 BB rootstock was generally superior in terms of rooting rate and root number, higher values were obtained than 420 A rootstock in terms of root length. There are similar findings in the literature regarding the success rates of different plant species in the cutting propagation process. For example, it is supported by research that some plant species are more difficult to propagate by cutting and have low success rates (Hartmann et al., 2011; Gunes & Eraslan, 2021).

Sharma et al. (2018) used an aeroponic medium in their cutting propagation studies on an evergreen tree species (*Tamarix aphylla* L. Karst) and reported successful results. Despite using very low auxin concentrations (1-10 ppm), the researchers achieved over 80% rooting success in some applications in the aeroponic medium. Tokunaga et al. (2020) observed that many new soil-borne diseases emerged during the propagation process of the Caysana (Manihot esculenta Crantz) plant, which is widely propagated by cuttings in Africa, Latin America, and Southeast Asia, and conducted experiments on cutting propagation in the aeroponic system to eliminate this problem and grow disease-free plant seedlings. As a result of the experiments, it was reported that the aeroponic system was effective in growing disease-free plants, and the cuttings in this system rooted in a shorter time compared to cuttings planted in the soil, and the rooting percentage and the number of roots per cutting were significantly higher.

Mehandru et al. (2014) studied the effect of different hormone forms and doses in their studies to test the effect of aeroponic culture in the propagation of some endemic plants grown in India by cutting and as a result of the experiment, they pointed out that aeroponic medium gave significantly more successful results compared to soil medium in all species they used. Nishchitha et al. (2023) compared mulberry (*Morus sp*.) cuttings by rooting them in the aeroponic system and under the nursery. As a result of the study, maximum root length (26.9 cm), root number (46.8), root biomass (1.17), shoot number (6.63), and shoot length (24.55) values were obtained from 3-bud mulberry cuttings (S1T3) rooted in the aeroponic system. It was concluded in the studies that the aeroponic system can be used effectively.

A study was conducted by Şimşek and Gül (2018) using three different rooting media (peat+perlite, silt, and aeroponic media) on four different evergreen, woody ornamental plant species (*Ficus nitida retusa*, *Pittosporum tobira nana* L., *Buxus sempervirens* L., and *Nerium oleander* L.). As a result of the study, it was concluded that the Aeroponic system was more successful in rooting than other classical rooting systems in all selected plant species. A study was conducted by Rostami and Mohavedi (2016) to investigate the feasibility of producing valerian (*Valeriana officinalis* L.) in the Aeroponic system and the effects of different concentrations of NAA hormone (0, 0.1, 0.3 and 0.5 mg/l) on morphological and physiological properties. It was concluded that the system was successful in root length, root volume and other parameters.

Studies also suggest that the rate of decay is related to moisture levels. It has been noted that lower irrigation rates can reduce decay and promote better rooting in plant materials, particularly wood cuttings (Salisbury and Ross, 1992).

There are also studies on the effect of cutting time on rooting. There are studies indicating that cuttings taken in a certain season or period have better rooting rates for some plant species. The findings obtained from the literature support the results observed in the study. We can say that it is consistent with the results of previous studies, especially in understanding the effects of growth regulators, rooting media and cutting time on rooting performance.

Although these methods offer promising solutions, there are still challenges to be solved. For example, the economic viability of soilless systems and their integration into circular economy models have been the subject of recent research in sustainable agriculture practices (Gonnella & Renna, 2021). In addition, the feasibility of utilizing plant growth-promoting microorganisms in soilless agriculture, especially in hydroponics and vertical farming, has been of interest in terms of improving productivity and nutritional quality (Dhawi, 2023).

Kaur et al. (2023) stated that according to the United Nations FAO report, there will be a huge demand for food worldwide and this demand is expected to increase by 70% by 2050. Basic parameters such as decreasing resources, global population and climate change challenge traditional agriculture.

As a result, soilless cultivation methods such as hydroponics and aeroponics have emerged as innovative approaches with the potential to solve various agricultural and environmental challenges. Their applications range from precisely controlled greenhouse cultivation to urban agriculture, offering food security, ecological sustainability, and urban development solutions. The study results revealed the positive effects of aeroponic systems on the rooting performance of grapevine rootstocks. In particular, significant improvements in rooting rate, root length, and root number were observed. This demonstrates aeroponic systems' applicability and efficiency in grapevine rootstock cultivation.

Significant improvements were also observed in this system in terms of root quality, especially in the aeroponic environment, longer, thicker, and more numerous roots were obtained.

Considering global challenges such as climate change and the reduction of agricultural areas, it is predicted that aeroponic systems will become even more important in the future. In this context, the advantages offered by aeroponic systems in the production of high economic value plants such as grapevines will play a critical role in terms of sustainability and efficiency in agriculture.

Conclusion

The study focused on the performance of 110R, 1103 Paulsen, and 5BB grapevine rootstocks in an aeroponic environment in propagation by cuttings with different doses of growth regulator (IBA). It was determined that IBA applications in aeroponic systems positively affected rooting rates in grapevine rootstock cuttings.

These results emphasize that the choice of growth regulators and rooting systems that propagate plant species from cuttings may affect rooting performance.

In conclusion, this study reveals that some of the grapevine rootstocks commonly used in our country can be successfully rooted in aeroponic systems and this method may find wider application in the future.

Declarations

This article was produced from master thesis

Author Contribution Statement

Deniz İpek: Project administration, Data collection, investigation, formal analysis, and writing the original draft

Hakan Karadağ: Project administration, formal analysis, supervision, conceptualization, methodology, writing the original draft review and editing

Fund Statement

This work was not founded by any institution/organization.

Conflict of Interest

The authors declare no conflict of interest.

Acknowledgments

I would like to thank Agricultural Engineer Fatma Dumlu for her support throughout the study.

References

Anonymous, 2022. Ankara University Open Lecture Notes https://acikders.ankara.edu.tr/pluginfile.php/10945/mod_resource/content/0/Konu%205.pdf

Anonymous, 2023. https://www.fao.org/faostat/en/#home (Access date: 02.10.2023)

Akakpo, D., Amissah, N., Yeboah J., Blay, E., (2014) "Effect of Indole 3-Butyric Acid and Media Type on Adventitious Root Formation in Sheanut Tree (Vitellaria paradoxa C. F. Gaertn.) Stem Cuttings," American Journal of Plant Sciences, Vol. 5 No. 3, 2014, pp. 313-318. doi: 10.4236/ajps.2014.53043.

Anonymous, (2023). Modern Farmer. https://web.archive.org/web/20150425225526/http://modernfarmer.com/2015/03/say-hello-to-the-soon-to-be-worlds-largest-indoor-vertical-farm/ Access date: 28.12.2023

Armı R. Patolıya, Laxmı D. Chauhan, Urmıla B. Bambhanıya, Solankı V. D., Paıja N. A., Bhoya R. N., Chıtroda R. L., Kanzarıa D. R. And Thumar K. P (2023). Hydroponıcs And Aeroponıcs System For Lettuce Crop. Peer Reviewed & Refereed | International Multidisciplinary Journal Of Applied Research. Volume-3 / Year –10 / Issue –6 / January – 2023

Aküzüm, T., Çakmak, B., & Gökalp, Z. (2019). Türkiye'de Su Kaynakları Yönetiminin Değerlendirilmesi. International Journal of Agricultural and Natural Sciences, 3(1), 67-74. Retrieved from http://www.ijans.org/index.php/ijans/article/view/86

Blythe, K.E., Sibley J.L., Tilt, K.M., Ruter, J.M. (2007). Methods of Auxin Application in Cutting Propagation: A Review of 70 Years of Scientific Discovery and Commercial Practice. Journal of Environmental Horticulture (2007) 25 (3): 166–185. https://doi.org/10.24266/0738-2898-25.3.166

Baciu, E.-D.; Baci, G.-M.; Moise, A.R.; Dezmirean, D.S. 2023. A Status Review on the Importance of Mulberry (Morus spp.) and Prospects towards Its Cultivation in a Controlled Environment. Horticulturae, 9, 444. https://doi.org/10.3390/horticulturae9040444

Çelik, H. (2012). Türkiye bağcılığı ve asma fidanı üretimi-dış ticareti ile ilgili stratejik bir değerlendirme. Türkiye Tohumcular Birliği (TÜRKTOB) Dergisi, 4, 10-16.

Dhawi, F. (2023). Role of Plant Growth Promoting Microorganisms (PGPMs) and Applicability in Hydroponic and Vertical Farming. Metabolites, 13 (2), 247. https://doi.org/10.3390/metabo13020247

Demirbas, A. (2019). Yağ Gülü (*Rosa Damascena* Mıll.)'Nde Çelik Alma Zamanı Ve Hormon Uygulama Şekillerinin Köklenme Oranı ve Fidan Gelişimi İle Bünyesel Fenolik Madde İçeriği Üzerine Etkisi. Isparta Uygulamalı Bilimler Üniversitesi Lisansüstü Eğitim Enstitüsü. ISPARTA

FAUB, 2022. Fidancılık Sektör Analizi Ve Geliştirme Raporu. Ankara 2022.

Gargın, S., İşçi, B., Altındişli, A., (2011). 41 B Amerikan Asma Anacı İle Aşılı Bazı Üzüm Çeşitlerinin Aşı Uyuşma Katsayıları Üzerine Bir Araştırma. C.B.Ü. Soma Meslek Yüksekokulu Teknik Bilimler Dergisi Yıl:2011 Cilt:1 Sayı:15

Gurley, W.T. (2020) Aeroponics: Growing Vertical. CRC Press 6000 Brooken Sound Parkway Nw, Suite 300, Boca Raton ISSN: 978-0-367-40953-1

Güneş, M., & Eraslan, D. (2021). Kuşburnu Odun Çeliklerinin Köklenmesi Üzerine Bazı Ortam ve Uygulamaların Etkisi. Gaziosmanpaşa Bilimsel Araştırma Dergisi, 10(2), 131-139.

Gonnella, M., Renna, M. (2021). Evolution Of Soilless Systems Towards Ecological Sustainability İn A Circular Economy Perspective. Is İt Really The Opposite Of Organic Farming? Agricultural Science, 11 (5), 950. https://doi.org/10.3390/agronomy11050950

Hartmann, H. T., Kester, D. E., Davies, F. T., & Geneve, R. L. (2011). Plant propagation: Principles and practices. Prentice Hall.

Kaur, G., Upadhayaya, P., Chawla, P. (2023). The Study of Sensors in Soil-Less Farming Techniques for Modern Agriculture. In: Kumar, H., Jain, P.K., Goel, S. (eds) Recent Advances in Intelligent Manufacturing. ICAME 2022. Lecture Notes in Mechanical Engineering. Springer, Singapore. https://doi.org/10.1007/978-981-99-1308-4_24

Kelen, M., & Demirtaş, İ. (2001). 5 BB ve 420 A Amerikan Asma Anaçlarının Köklenme Oranları ve Kök Kaliteleri Üzerine Farklı Köklendirme Ortamları ile IBA Dozlarının Etkileri. Journal of Agricultural Sciences, 07(01), 142-146. https://doi.org/10.1501/Tarimbil_0000000269

Kratsch, H.A., Graves, W.R., Gladon, R.J. (2006). "Aeroponic system for control of root-zone atmosphere" Environmental and Experimental Botany, Volume 55, Issues 1–2, Pages 70-76 ISSN 0098-8472, https://doi.org/10.1016/j.envexpbot.2004.10.002.

Kumari, R., Kumar, R., 2019. Aeroponics: A Review on Modern Agriculture Technology. Indian Farmer 6(4): 286-292; April-2019

Lakhiar, I. A., Gao, J., Syed, T. N., Chandio, F. A., & Buttar, N. A. (2018). Modern plant cultivation technologies in agriculture under controlled environment: A review on aeroponics. Journal of Plant Interactions, 13(1), 338-352.

Lakhiar, I. A., Gao, J., Syed, T. N., Chandio, F. A., Tunio, M. H., Ahmad, F., & Solangi, K. A. (2020). Overview of the aeroponic agriculture–An emerging technology for global food security. International Journal of Agricultural and Biological Engineering, 13(1), 1-10.

Mehandru, P., Shekhawat, N.S., Rai, M.K. (2014). Evaluation of aeroponics forclonalpropagation of Carallumaedulis, Leptadeniareticulataand Tylophoraindica – three threatened medicinal Asclepiads. PhysiolMolBiolPlants 20, 365–373. https://doi.org/10.1007/s12298-014-0240-8

Mateus-Rodriguez, J. F., Haan, S. d., Andrade-Piedra, J., Maldonado, L., Hareau, G., Barker, I. K., & Benítez, J. (2013). Technical And Economic Analysis Of Aeroponics And Other Systems For Potato Mini-Tuber Production İn Latin America. American Journal of Potato Research, 90(4), 357-368. https://doi.org/10.1007/s12230-013-9312-5

Marcynuk, A. (2011). Urban growth: a synthesis of agriculture and architecture (Doctoral dissertation, Carleton University).

Misganaw, C.D. (2021). The Practice of Urban Farming is the Most Valuable Tool in the Fight Against Famine, Depression, Anxiety and the Spread of Coronavirus.http://www.sciencepublishinggroup.com/j/aff

Nishchitha GA, Bhaskar RN, Bharathi VP, Anusha HG. Aeroponic system is boon for rainfed mulberry cultivation and enhance productivity. Pharma Innovation 2023;12(3):4480-4484.

Nir, I. (1982). Growıng Plants In Aeroponıcs Growth System. Acta Hortic. 126, 435-448 https://doi.org/10.17660/ActaHortic.1982.126.49

Nederhoff, E., Stanghellini, C. (2010). Water Use Efficiency of Tomatoes. Practical Hydroponics and Greenhouses, (115), 52–59. https://search.informit.org/doi/10.3316/informit.484066941930798

Peterson L, A.,Krueger A, R., An intermittent aeroponic system. CropSci. 1988;28:712–713. doi: 10.2135/cropsci1988.0011183X002800040033x.

Pulighe, G. ve Lupia, F. (2020). Food first: The COVID-19 pandemic and the lockdown of cities contribute to a broader vision of urban agriculture. Sustainability, 12 (12), 5012.

Rostami, M., Movahedi, Z. (2016). Evaluatingtheeffects of Naphthaleneaceticacid (NAA) on morpho-physiologicaltraits of valerian (*Valeriana officinalis* L.) in aeroponic system. IranianJournal of PlantPhysiology, 6(3), 1751-1759.

Rajan, R. P., Sravani, G. C., (2021). Advanced and modern fruit productiontechniques: A review. The Pharma Innovation Journal 2021; 10(7): 938-943

Roffi, T. M., Jamhari, C. A. (2023). Internet Of Things Based Automated Monitoring For İndoor Aeroponic System. International Journal of Electrical&ComputerEngineering (2088-8708), 13(1).

Rani, R. S., Kumar, H. V., Mani, A., Reddy, B. S., & Rao, C. S. (2022). Soilless Cultivation Technique, Hydroponics-A Review. Current Journal of Applied Science and Technology, 41(13), 22-30.

Regas, T., Han, J. H., Pauli, C. S., Park, S. H. (2021). Employing Aeroponic Systems for the Clonal Propagation of Cannabis. J Vis Exp. 2021 Dec 1;(178). doi: 10.3791/63117. PMID: 34927616

Sagheer, A.,Mohammed, M., Riad, K. ve Alhajhoj, M. (2020). A cloud-based IoT platform for precise control of hydroponic greenhouse cultivation sensors, 21 (1), 223. https://doi.org/10.3390/s21010223

Sağlam, H., Çalkan Sağlam, Özlem, Karakoyun, M. (2023). A Study on the Determination of Rooting Characteristics of Some Vine Rootstocks. MAS Journal of Applied Sciences, 8(1), 103–108. https://doi.org/10.5281/zenodo.7664498

Salisbury, F.B., Ross, C.W. (1992) Weed Technology , Volume 6 , Issue 1 , March 1992. pp. 238 DOI: https://doi.org/10.1017/S0890037X0003462X

Sahoo, D. (2020). Aeroponics System of Cultivation in Horticultural Crops. Just Agriculture The Future of Agri İnnovation. Vol.1 Issue-1 P:32-40, September, 2020

Sukhjit, K. 2015. "Effect of different treatments of Indole-3-butyric acid (IBA) on the rooting and growth performance of hardwood cuttings of peach (Prunus persica L. Batch)". Agricultural Science Digest. Volume : 35, Issue : 1 First page : (41) Last page : (45) Print ISSN : 0253-150X. Online ISSN : 0976-0547. Article DOI : 10.5958/0976-0547.2015.00008.7

Şimşek, A., Gül, A., (2018). Süs Bitkisi Fidanı Üretiminde Aeroponik (Aerofog) Sistemi ile Diğer Klasik Köklendirme Ortamlarının Karşılaştırılması. Süleyman Demirel Üniversitesi Fen Bilimleri Enstitüsü Dergisi Cilt 22, Sayı 2, 760-767, 2018 DOI: 10.19113/sdufbed.91314

Sharma, U., Kataria, V., Shekhawat, N.S., 2018. Aeroponics foradventitiousrhizogenesis in evergreenhaloxerictreeTamarixaphylla (L.) Karst.: influence of exogenousauxinsandcuttingtype. PhysiolMolBiolPlants (January–February 2018) 24(1):167–174https://doi.org/10.1007/s12298-017-0493-0

Sharma, A., Manpoong, C., Devadas, V. S., Kartha, B. D., Pandey, H., & Wangsu, M. (2022). Crop hydroponics, phyto-hydroponics, crop production, and factors affecting soilless culture. ACS Agricultural Science & Technology, 2(6), 1134-1150.

Tokunaga, H., Anh, N, H., Dong, N, D., Ham, L, H., Hanh, N, T., Hung, N., Ishitani, M., Tuan, L, N., Utsumi, Y., Vu N,A., Seki, M. 2020. An Efficient Method Of Propagating Cassava Plants Using Aeroponic Culture, Journal of CropImprovement, 34:1, 64-83, DOI:10.1080/15427528.2019.1673271

Yağcı, A., Erdem A., 2019. Amerikan Asma Anaçlarının Kullanım Nedenleri Ve Bazı Anaçların Özellikleri. https://arastirma.tarimorman.gov.tr/manisabagcilik/Belgeler/genelbagcilik/AMERIKAN%20ANACLARI%20ADEM%20YAGCI.pdf