Veterinary Medicine and Public Health Journal (VMPH)

Volume.5, Issue.2, pp: 27-34 Article 1
May (2024)

Effect of Planting Media and Cultivation Method in the Offshoots Growth of Date Palm *Phoenix Dactylifera* L. Hillawi cv.

Abdul Samad A. Abdullah, Hassan A. Faisal, Khairullah M. Awad

Received: 15/12/2023 **Revised:** 15/1/2024 **Accepted:** 17/2/2024

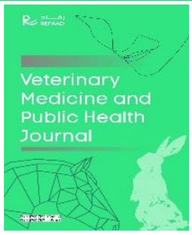
DOI: https://doi.org/10.31559/VMPH2024.5.2.1

REFAAD
www.refaad.com

Veterinary Medicine and Public Health Journal (VMPH)

Journal Homepage: https://www.refaad.com/Journal/Index/7

E-ISSN 2707-7195 | P-ISSN 2707-7187



Effect of Planting Media and Cultivation Method in the Offshoots Growth of Date Palm *Phoenix Dactylifera* L. Hillawi cv.

Abdul Samad A. Abdullah[1*], Hassan A. Faisal[1], Khairullah M. Awad[1]
[1] Date Palm Research Center, Basrah University, Iraq.

*** Corresponding author:** Abdul Samad A. Abdullah (abdulsamad.abbood@uobasrah.edu)

How to cite this article: Abdullah, A., et al. (2024). Effect of Planting Media and Cultivation Method in the Offshoots Growth of Date Palm Phoenix Dactylifera L. Hillawi cv. Veterinary Medicine and Public Health Journal, 5(2), 27-34.

Abstract:
Objective: The study aimed to explore the effects of different planting medium on the growth of date palm Hillawi cv. offshoots.
Methods: The experiment included two main factors: the first factor was planting media, consisting of three treatments: field soil, zeolite + field soil (in a 2:1 ratio), and zeolite + sand (in a 2:1 ratio). The second factor was cultivation method, comprising three methods: traditional planting, container planting (using pots), and planting in lined holes with a layer of agricultural polyethylene (nylon).
Results: Planting medium significantly influenced the growth of the offshoots. Specifically, planting media with zeolite and sand exhibited significant improvements in leaf length, dry matter content, leaf area, root count, root length, and diameter compared to the control group. Conversely, the zeolite-field soil combination exhibited a marked increase in moisture content. Additionally, electrical conductivity (EC) within the planting media was notably higher in the control condition featuring only field soil. The study also found that the chosen cultivation method significantly influenced the growth of the offshoots. The lined holes method displayed significant advantages in leaf length, dry matter content, leaf area, root count, root length, root diameter, and moisture content within the planting media, compared to the traditional approach. Conversely, the traditional method resulted in higher EC within the planting media.
Conclusions: The study reveals significant effects of cultivation medium, method, and their interaction on various growth parameters of date palm offshoots. This study recommends the lined-hole planting method and zeolite-infused medium for enhanced offshoot growth.

Keywords: *EC; lined holes; moisture content; offshoots; zeolite.*

1 Introduction

Dry and semi-arid regions suffer from water scarcity, and the allocated share for agriculture diminishes over time due to increased food demand driven by population growth, agricultural expansion, and limited rainfall. Therefore, it is imperative to optimize water utilization to ensure the sustainability and enhancement of agricultural production (Ingrao et al., 2023). Moreover, agricultural soil in dry and semi-arid regions faces challenges of reduced crop growth and productivity. This is attributed to the soil's inadequate moisture retention and nutrient content (Naorem et al., 2023). Iraq also suffers from limited low-salinity water resources, which are crucial inputs for agricultural production and a fundamental pillar in agricultural development. Additionally, the practice of irrigated agriculture consumes a significant portion of water resources, reaching up to 90% in many countries situated in arid regions worldwide, including Iraq (Khafaji et al., 2022). Date palm orchards are plagued by neglect and a lack of agricultural services, leading to adverse effects on soil properties and subsequently, on tree growth and productivity (Almadini et al., 2021). The growth of date palm offshoots is influenced by various factors, including genetic factors linked to the plant's genetic composition. These genetic factors encompass attributes like high growth potential, good quality, resistance to drought and diseases, and others. Additionally, there are environmental factors that involve a set of conditions related to soil, irrigation water, and climate (Jaradat, 2016). Good soil characteristics are essential factors for achieving high rates of growth and development in date palm seedlings. Date palm seedlings thrive well in soils with a high water retention capacity, rich in organic matter, devoid of diseases, and free from harmful nutrients like boron and chlorine. Moreover, the presence of an effective drainage system further supports their growth (Aydi et al., 2023). The use of natural amendments and organic fertilizers enhances the physical, chemical, and fertility properties of the soil's surface layer, providing an optimal environment for plant growth. This includes an increase in moisture content and the availability of essential nutrients. Zeolite, in particular, has garnered significant attention for its role in enhancing the physical and chemical properties of soil (Hafez et al., 2021). Zeolite exhibits distinct physical, chemical, and mechanical properties, along with a notable high cation exchange capacity (Vasconcelos et al., 2023). Zeolite improves fertilizer efficiency by absorbing nitrogen, enhances the quality of organic fertilizers, and stands out for its high cation exchange capacity. Furthermore, zeolite enhances the soil's water retention capacity. Notably, the addition of zeolite significantly reduced both electrical conductivity (EC) and sodium content (Mondal et al., 2021). Several researchers have emphasized that raw zeolite contains a substantial amount of essential nutrients, contributing to plant needs and fostering a favorable nutritional environment for plant growth and increased productivity. Moreover, zeolite enhances the horizontal water distribution within the soil reviewed by (Cataldo et al., 2021).

Due to quite few of studies addressing the failure of newly planted date palm offshoots in permanent soil, his study aimed to investigate the impact of planting media on the success and growth of Hillawi cultivar date palm offshoots. The study also aimed to assess the effects of zeolite addition to the planting media, analyzing its influence on media properties, moisture content, and its potential to mitigate salt stress. Additionally, the study aimed to examine the significance of cultivation methods on the success and growth of Hillawi cultivar date palm offshoots.

2 Materials and Methods

The field experiment for this study was conducted in a private orchard located in the Abu Al-Khasib district, southeast of Basra Governorate, Iraq. The experiment included two main factors: the first factor was planting media, consisting of three treatments: field soil, zeolite + field soil (in a 2:1 ratio), and zeolite + sand (in a 2:1 ratio). The second factor was cultivation method, comprising three methods: traditional planting, container planting (using pots), and planting in lined holes with a layer of agricultural polyethylene (nylon). Twenty-seven Hillawi date palm offshoots at four years old, uniform in growth and size as much as possible, were selected. All seedlings were treated with insecticides to eliminate insect pests and fungicides to prevent fungal diseases and rot. The seedlings were planted at the beginning of the spring growing season on March 23, 2018, and were covered using palm leaves and agricultural netting to protect them from direct sunlight and reduce water loss due to transpiration and evaporation from leaf surfaces.

Preparation of Planting Media:

Zeolite:

The natural zeolite "Zap77" utilized in the study was sourced from Jordan and imported by the Ministry of Agriculture's General Company for Agricultural Supplies through their exclusive distributor, Gheras General Trading Company Limited. The physical and chemical properties of this zeolite are as follows: it has a pH of 8.0, an electrical conductivity (EC) of 0.465 (dS/m), a total porosity of 48.24%, a positive cation exchange capacity (CEC) of 24.03 (Cmol/kg), an organic matter content of 0.48 g/kg, and a calcium carbonate ($CaCO_3$) content of 58.73 g/kg.

Sand:

The sand used in the study was sourced from quarries in Al-Zubair district, and it underwent a sieving process using a sieve with a 1mm opening diameter. This process allowed the collection of fine sand while excluding the coarse particles. The sand properties are as follows: pH (1:1) of 8.73, electrical conductivity (Ec) of 5.91 dS/m, calcium carbonate ($CaCO_3$) content of 69.15 g/kg, organic matter content of 0.12 g/kg, total nitrogen content of 0.06 g/kg, and available phosphorus content of 0.005 g/kg. The soil texture components are separated by weight: sand at 806.00 g/kg, silt at 141.00 g/kg, and clay at 53.00 g/kg. The soil texture is classified as sandy loam.

Field soil:

The field soil used in the study has similar properties as the soil employed in the research, with some of its physical and chemical characteristics outlined below. The pH (1:1) is 7.71, the electrical conductivity (Ec) is 11.05 dS/m, the calcium carbonate ($CaCO_3$) content is 49.34 g/kg, the organic matter content is 26.35 g/kg, the available nitrogen content is 6.16 g/kg, and the available phosphorus content is 0.69 g/kg. The soil texture components by weight are as follows: sand at 46.5 g/kg, silt at 473.5 g/kg, and clay at 480.0 g/kg. The soil texture is classified as clay loam.

Planting methods:

Traditional planting method:

The traditional planting method, commonly practiced in most date palm cultivation areas, involves digging nine holes in the ground with a diameter of approximately 60 cm and a depth of 60 cm. These holes are then filled with planting media to a level of 50 cm, with a total of three holes for each planting medium.

Container planting method:

The container planting method involved using nine cylindrical containers with a diameter of 60 cm and a depth of 60 cm. Holes were made at the bottom of each container to prevent waterlogging of the planting medium. Each These containers were placed on a level surface with a distance of one meter between each container. container was then filled with one of the three planting media to a level of 50 cm. This setup included a total of three containers for each planting medium.

Lined hole planting method:

The lined hole planting method consisted of creating nine holes in the field with a diameter of 60 cm and a depth of 60 cm. At the base of each hole, a layer of coarse gravel, approximately 10 cm thick, was placed to prevent the rise of groundwater into the planting medium. Subsequently, a layer of polyethylene (nylon) was positioned within each hole, covering the bottom and sides of the hole. Holes were made in the covering nylon layer at the base of each hole to allow excess water from irrigation to drain and prevent waterlogging and root rot. The planting media were then added to the holes, with three holes allocated for each planting medium.

The studied traits:

After approximately one year from planting the offshoots on 25/3/2019, the offshoots were uprooted, and measurements and required samples were taken to study the following traits and indicators:

Leaf Length Growth Rate: The lengths of leaves for each offshoot were measured both at planting and at the end of the experiment. The leaf length growth rate was calculated by subtracting the length of the frond before planting from the length of the frond after planting, then dividing the result by the number of fronds.

Leaf Area:

The leaf area was calculated by taking four leaflets (fronds) from the third row of leaves, starting from the top of the growing direction of each offshoot. The average length and width of each leaflet were calculated, and then the leaflet area was derived using the following equation according to (Demirsoy, 2009).

$$\text{Leaf area } (\text{m}^2) = \frac{0.37 * (length\ of\ leaflets * width\ of\ leaflets) + 10.29 * number\ of\ leaflets}{10000}$$

Then, the leaf area for each offshoot was calculated using the following equation:

Total Leaf Area (m²) = Leaflet Area × Number of Leaflets in the Offshoot

Number of Roots:

The count of roots formed at the base of each offshoot was determined after uprooting them from the growing medium and carefully cleaning them to avoid damaging the roots.

Average Root Length (cm):

The lengths of the roots for each offshoot were measured using a measuring tape. The average root length for each offshoot was then calculated by dividing the total sum of root lengths by the number of roots in that offshoot.

Average Root Diameter (mm):

The diameters of the roots for each offshoot were measured at their widest points using a Vernier caliper. The average root diameter for each offshoot was then calculated by dividing the total sum of root diameters by the number of roots in that offshoot.

Leaf Dry Matter Content (%):

The dry matter content percentage in the leaves was estimated by taking samples of the leaflets (fronds) from the third-row leaves, post-emergence. After thoroughly washing the root and leaf samples, each sample was weighed using a sensitive electronic balance. Then, the samples were dried in an electric oven at a temperature of 70°C until a constant weight was reached. The percentage of dry matter content was calculated using the following equation:

$$Dry\ mater\ (\%) = \frac{\text{Dry weight}}{Fresh\ weight} * 100$$

Moisture Content of Growing Media:

The percentage of weight moisture content was determined using the method proposed by Gardner and described in (Holliday, 1990).

Electrical Conductivity (EC):

The electrical conductivity was measured in the extract of saturated soil paste using an EC-meter following the method outlined in (Slavich & Petterson, 1993).

Experimental Design and Statistical Analysis:

The experiment was conducted using a Randomized Complete Block Design (R.C.B.D.) as a factorial experiment with two factors: the first factor representing the growth media and the second factor representing the cultivation methods. Each treatment combination was replicated three times. The obtained data were subjected to statistical analysis using the Gen Stat statistical software. Mean comparisons were performed using the Least Significant Difference (L.S.D.) test at a significance level of 0.05.

3 Results and Discussion

The results presented in Table 1 show that the growth media had a significant effect on the leaf length growth rate. The growth media (zeolite + sand) significantly outperformed other media, with a recorded value of 29.42 cm. Additionally, the cultivation methods exhibited a significant impact on the leaf length growth rate, with the "furrow" method showing the highest growth rate at 27.72 cm. Regarding interaction effects, the treatment combining zeolite + sand with lined holes method displayed a significant improvement compared to all other treatments, including the control treatment, with a recorded value of 30.23 cm.

Table 1: Effect of planting Medium, Cultivation Method, and their Interaction on Leaf Length Increase Rate (cm)

Planting method	Planting media			Mean of planting method
	Field soil	Zeolite +field soil	Zeolite +sand	
Traditional method	21.49	27.61	9.08	26.06
Container	23.37	28.40	28.95	26.58
Lined holes	23.69	29.23	30.23	27.72
Mean of planting media	22.52	28.41	29.42	
LSD ($p<0.05$) for planting method and planting media= 0.562; for interaction =0.973				

The results of Table 2 demonstrate a significant effect of the growing medium on the leaf dry matter percentage, where the growing medium of (zeolite + sand) and (zeolite + field soil) significantly outperformed the control treatment, recording values of 53.62 and 53.30, respectively. The table also reveals that the cultivation method has an impact on the same attribute, with the "lined holes" method significantly surpassing the control treatments traditional and containers, recording a value of 53.44. Regarding the interaction effects, the treatment combining zeolite + sand and lined holes demonstrated significant superiority over the control treatment, recording the highest value of 56.12. Following closely, the treatment zeolite + field soil and lined holes recorded a value of 55.84, showing a significant difference from the control treatment, which had the lowest value of 43.62.

Table 2: The impact of the planting medium, cultivation method, and their interaction on the leaf dry matter (%).

Planting method	Planting media			Mean of planting method
	Field soil	**Zeolite +field soil**	**Zeolite +sand**	
Traditional method	43.62	52.65	52.99	49.75
Container	45.99	51.40	51.75	49.71
Lined holes	48.36	55.84	56.12	53.44
Mean of planting media	45.99	53.30	53.62	
LSD ($p<0.05$) for planting method and planting media= 0.613; for interaction =1.062				

The results from Table 3 indicate a significant effect of the planting media on the leaf area, where the treatment with the mixed growing medium (zeolite + sand) and (zeolite + field soil) demonstrated significant superiority over the control treatment, recording values of 0.540 m^2 and 0.537 m^2 sequentially, compared to the control treatment's value of 0.508 m^2. Additionally, the table shows a statistically significant impact of the cultivation method, with the "lined holes" and "containers" treatments outperforming the control treatment, recording values of 0.543 m^2 and 0.534 m^2 sequentially, with a significant difference from the control treatment's value of 0.507 m^2. The interaction between the growing medium and the cultivation method also displayed a significant effect on the leaf area. The treatment combining the mixed growing medium (zeolite + sand) with the lined holes cultivation method achieved the highest value of 0.552 m^2, which was significantly different from the control treatment's value of 0.527 m^2.

Table 3: illustrates the effect of the growing medium, cultivation method, and their interaction on the leaf area (m^2).

Planting method	Planting media			Mean of planting method
	Field soil	**Zeolite +field soil**	**Zeolite +sand**	
Traditional method	0.483	0.514	0.527	0.507
Container	0.515	0.546	0.542	0.534
Lined holes	0.526	0.551	0.552	0.543
Mean of planting media	0.508	0.537	0.540	
LSD ($p<0.05$) for planting method and planting media= 0.0156; for interaction =0.0271				

The results in Table 4 revealed a significant impact of the planting media on the number of roots formed in each offshoot. The planting media composed of (zeolite + sand) exhibited a significant superiority over both the medium composed of (zeolite + field soil) and the comparison medium (field soil), recording a value of 33.89. Additionally, the cultivation method had a significant effect on the number of roots formed. The treatment involving the lined holes method demonstrated significant superiority over the container method and the traditional method, recording a value of 29.89. Moreover, the interaction effects between the growing medium and cultivation method were statistically significant. The treatment involving (zeolite + sand) and lined holes exhibited the highest values, reaching 37.33, which was significantly different from the comparison treatment, recording the lowest value of 13.00.

Table 4: Effect of planting media, Cultivation Method, and their Interaction on Number of Roots

Planting method	Planting media			Mean of planting method
	Field soil	**Zeolite +field soil**	**Zeolite +sand**	
Traditional method	13.00	26.00	32.00	23.89
Container	19.00	29.00	32.33	26.78
Lined holes	21.33	31.00	37.33	29.89
Mean of planting media	18.00	28.67	33.89	
LSD ($p<0.05$) for planting method and planting media= 1.414; for interaction =2.446				

The results from Table 5 indicate that the planting media factor has a significant effect on the average root length. The growing medium (zeolite + Sand) outperformed the medium (zeolite + Field Soil) and the comparison medium (Field Soil) significantly, with a recorded value of 47.54 cm. Furthermore, the cultivation method also had a significant effect on the average root length, with the method of Lined holes surpassing the comparison method and recording a value of 45.76

cm. Additionally, the interaction between the growing medium and cultivation method showed a significant impact on the average root length. treatment and all other interaction treatments, registering a value of 49.45 cm.

The interaction treatment (zeolite + Sand) and Lined holes outperformed the comparison

Table 5: The impact of the planting media, cultivation method, and their interaction on the average root length (cm)

Planting method	Planting media			Mean of planting method
	Field soil	Zeolite +field soil	Zeolite +sand	
Traditional method	41.09	43.09	45.64	43.28
Container	42.05	45.32	47.53	44.97
Lined holes	42.34	45.50	49.45	45.76
Mean of planting media	41.83	44.64	47.54	
LSD ($p<0.05$) for planting method and planting media= 0.950; for interaction =1.646				

The results shown in Table 6 indicate that the planting media has a significant effect on the average root diameter. The treatment with the growing medium (zeolite + sand) outperformed significantly both treatments with the growing medium (zeolite + field soil) and the comparison treatment (field soil), with recorded values of 6.482 mm. The results also reveal that the cultivation method has an impact on the average root diameter, with the method of lined holes showing a significant superiority over the methods of container and traditional cultivation, recording a value of 5.643 mm. Additionally, the interaction between the growing medium and cultivation method had a significant effect on the average root diameter. The treatment with the interaction of (zeolite + sand) and lined holes recorded the highest value of 7.497 mm, showing a significant difference from both the comparison treatment and all other interaction treatments.

Table 6: The impact of the planting media, cultivation method, and their interaction on the average root diameter (mm).

Planting method	Planting media			Mean of planting method
	Field soil	Zeolite +field soil	Zeolite +sand	
Traditional method	3.580	4.910	5.683	4.720
Container	3.783	5.670	6.280	5.249
Lined holes	3.800	5.633	7.497	5.643
Mean of planting media	3.721	5.409	6.482	
LSD ($p<0.05$) for planting method and planting media= 0.235; for interaction =0.407				

A high quantity of nutrients contributes to fulfilling a portion of the plant's needs and creates a favorable nutritional environment for plant growth (Ahmed et al., 2006). The increase in vegetative growth of plants might be attributed to the fact that zeolite potentially reduces the leaching of mineral nitrogen by adsorbing it onto the zeolite particle surfaces, preventing its loss from the growing medium in the form of ammonia (Bundan et al., 2011). As for the effect of the cultivation method, its impact on improving vegetative and root growth characteristics could be attributed to providing an optimal moisture level that can be controlled. Additionally, it may help reduce salt stress experienced by the offshoots compared to those cultivated in the field soil using traditional methods.

The results presented in Table 7 indicate that the cultivation medium factor has a significant effect on moisture content. The cultivation mediums (zeolite + field soil) and (zeolite + sand) outperformed the comparison treatment (field soil), recording values of 15.903 and 15.733, respectively. This difference was statistically significant. Moreover, the cultivation method factor also had an impact on moisture content, as the method of cultivation using lined holes significantly surpassed the cultivation methods containers and traditional along with the comparison treatment. The lined holes method recorded a value of 15.733.

Table 7: Effect of Cultivation Medium, Cultivation Method, and their Interaction on Moisture Content of Cultivation Mediums

Planting method	Planting media			Mean of planting method
	Field soil	Zeolite +field soil	Zeolite +sand	
Traditional method	12.810	15.224	15.410	14.481
Container	13.003	15.493	15.565	14.687
Lined holes	13.984	16.991	16.225	15.733
Mean of planting media	13.266	15.903	15.733	
LSD ($p<0.05$) for planting method and planting media= 0.334; for interaction =0.578				

The higher moisture content observed in the polyethylene-lined holes might be attributed to the presence of the polyethylene layer, which could restrict the spread of irrigation water within the soil and maintain it within the holes. This is in contrast to the traditional cultivation method, where a portion of the irrigation water might be lost due to its wider spread within the soil. The superiority of the lined holes over the container cultivation method could be explained by the loss of irrigation water through evaporation caused by direct sunlight exposure on the containers, which is not the case with the lined holes. The interaction between cultivation medium and cultivation method also had a significant effect on moisture content. The treatment with medium (zeolite + field soil) and lined holes outperformed all other treatments significantly, including the control treatment, recording a value of 16.991. In comparison, the control treatment had the lowest value at 12.810. The influence of zeolite on moisture content could be attributed to its role in enhancing soil water retention due to its crystalline structure with significant porosity. This structure allows zeolite to effectively hold water molecules within its pores, facilitating easier water absorption by plants (Ibrahim & Alghamdi, 2021). Additionally, zeolite's moisture-wicking and re-wetting capabilities play a crucial role in maintaining soil moisture balance and protecting it from drying out (Jarosz et al., 2022).

The results from Table 8 revealed that the cultivation medium had a significant effect on electrical conductivity. The control treatment (field soil) outperformed both medium treatments (zeolite + sand) and (zeolite + field soil) significantly, registering a value of 4.952. Similarly, the cultivation method had an impact on electrical conductivity. The control treatment (conventional method) outperformed both container and lined holes' methods significantly, with a value of 4.352. The interaction between the cultivation medium and method also influenced electrical conductivity. The treatment involving the control medium (field soil) and the conventional method had the highest value, reaching 4.635.

This could potentially be attributed to the smaller pore size of the field soil, which could limit leaching and salt washing compared to the media that included zeolite. Zeolite's presence played a role in adsorbing salt ions within its porous structure due to its cationic exchange capacity. This resulted in an increased efficiency of salt leaching during irrigation, as the salt ions were exchanged with other ions present in the cultivation medium. This exchange mechanism could enhance the removal of salts from the soil and contribute to better salt leaching efficiency (Mondal et al., 2021).

Table 8: Effect of Cultivation Medium, Method, and their Interaction on Electrical Conductivity (Ec) of planting Media

Planting method	Planting media			Mean of planting method
	Field soil	Zeolite +field soil	Zeolite +sand	
Traditional method	4.635	4.308	4.112	4.352
Container	4.623	4.124	3.269	4.005
Lined holes	4.519	4.130	3.293	3.981
Mean of planting media	4.592	4.187	3.558	
LSD ($p<0.05$) for planting method and planting media= 0.231; for interaction =0.400				

4 Conclusions

In conclusion, the study reveals significant effects of cultivation medium, method, and their interaction on various growth parameters of date palm offshoots. Zeolite inclusion in the medium and the lined holes cultivation method stand out as impactful factors for improved plant growth, root development, and moisture retention. These findings underscore the importance of optimized cultivation conditions to enhance agricultural outcomes and mitigate environmental stressors.

Recommendations:
This study recommends zeolite-infused medium and lined holes planting for enhanced growth of date palm offshoots.

Acknowledgments:
Not applicable

References:

Ahmed, O. H., Aminuddin, H., & Husni, M. H. A. (2006). Reducing ammonia loss from urea and improving soil-exchangeable ammonium retention through mixing triple superphosphate, humic acid and zeolite. *Soil Use and Management*, *22*(3), 315–319. https://doi.org/10.1111/j.1475-2743.2006.00040.x

Almadini, A. M., Ismail, A. I. H., & Ameen, F. A. (2021). Assessment of farmers practices to date palm soil fertilization and its impact on productivity at Al-Hassa oasis of KSA. *Saudi Journal of Biological Sciences*, *28*(2), 1451–1458. https://doi.org/10.1016/j.sjbs.2020.11.084

Aydi, S., Sassi Aydi, S., Rahmani, R., Bouaziz, F., Souchard, J. P., Merah, O., & Abdelly, C. (2023). Date-palm compost as soilless substrate improves plant growth, photosynthesis, yield and phytochemical quality of greenhouse melon (Cucumis melo L.). *Agronomy (Basel, Switzerland)*, *13*(1), 212. https://doi.org/10.3390/agronomy13010212

Bundan, L., Muhamad, N., Majid, A., Haruna, O., & Kundat, F. R. (2011). Ammonia volatilization from urea at different levels of zeolite. *International Journal of the Physical Sciences*, 6(34), 7717.

Cataldo, E., Salvi, L., Paoli, F., Fucile, M., Masciandaro, G., Manzi, D., … Mattii, G. B. (2021). Application of zeolites in agriculture and other potential uses: A review. *Agronomy (Basel, Switzerland)*, *11*(8), 1547. https://doi.org/10.3390/agronomy11081547

Demirsoy, H. (2009). Leaf area estimation in some species of fruit tree by using models as a non-destructive method. *Fruits*, 64(1), 45–51. https://doi.org/10.1051/fruits/2008049

Hafez, M., Popov, A. I., & Rashad, M. (2021). Integrated use of bio-organic fertilizers for enhancing soil fertility–plant nutrition, germination status and initial growth of corn (Zea Mays L.). Environmental Technology & Innovation, 21, art. No. 101329. https://doi.org/10.1016/j.eti.2020.101329

Holliday, V. T. (1990). Methods of soil analysis, part 1, physical and mineralogical methods (2nd edition), A. Klute, Ed., 1986, American Society of Agronomy, Agronomy Monographs 9(1), Madison, Wisconsin, 1188 pp. *Geoarchaeology*, *5*(1), 87–89. https://doi.org/10.1002/gea.3340050110

Ibrahim, H. M., & Alghamdi, A. G. (2021). Effect of the particle size of clinoptilolite zeolite on water content and soil water storage in a loamy sand soil. *Water*, 13(5), art. no. 607. https://doi.org/10.3390/w13050607

Ingrao, C., Strippoli, R., Lagioia, G., & Huisingh, D. (2023). Water scarcity in agriculture: An overview of causes, impacts and approaches for reducing the risks. *Heliyon*, *9*(8), e18507. https://doi.org/10.1016/j.heliyon.2023.e18507

Jaradat, A.A. (2016). Genetic Erosion of Phoenix dactylifera L.: Perceptible, Probable, or Possible. In: Ahuja, M., Jain, S. (eds) Genetic Diversity and Erosion in Plants. Sustainable Development and Biodiversity, vol 8. Springer, Cham (pp:131-213). https://doi.org/10.1007/978-3-319-25954-3_4

Jarosz, R., Szerement, J., Gondek, K., & Mierzwa-Hersztek, M. (2022). The use of zeolites as an addition to fertilisers – A review. *Catena*, 213, art. no. 106125. https://doi.org/10.1016/j.catena.2022.106125

Khafaji, M. S. A.-, Alwan, I. A., Khalaf, A. G., Bhat, S. A., & Kuriqi, A. (2022). Potential use of groundwater for irrigation purposes in the Middle Euphrates region, Iraq. *Sustainable Water Resources Management*, 8, art. no. 157. https://doi.org/10.1007/s40899-022-00749-3

Mondal, M., Biswas, B., Garai, S., Sarkar, S., Banerjee, H., Brahmachari, K., Bandyopadhyay, P.K., Maitra, S., Brestic, M., Skalicky, M., Ondrisik, P., Hossain, A. (2021). Zeolites enhance soil health, crop productivity and environmental safety. *Agronomy (Basel, Switzerland)*, 11(3), 448. https://doi.org/10.3390/agronomy11030448

Naorem, A., Jayaraman, S., Dang, Y. P., Dalal, R. C., Sinha, N. K., Rao, C. S., & Patra, A. K. (2023). Soil constraints in an arid environment—challenges, prospects, and implications. *Agronomy (Basel, Switzerland)*, 13(1), 220. https://doi.org/10.3390/agronomy13010220

Slavich, P. G., & Petterson, G. H. (1993). Estimating the electrical conductivity of saturated paste extracts from 1:5 soil, water suspensions and texture. Soil Research, *31*(1), 73-81. https://doi.org/10.1071/sr9930073

Vasconcelos, A. A., Len, T., de Oliveira, A. de N., Costa, A. A. F. da, Souza, A. R. da S., Costa, C. E. F. da, … Nascimento, L. A. S. do. (2023). Zeolites: A theoretical and practical approach with uses in (bio)chemical processes. *Applied Sciences (Basel, Switzerland)*, 13(3), 1897. https://doi.org/10.3390/app13031897